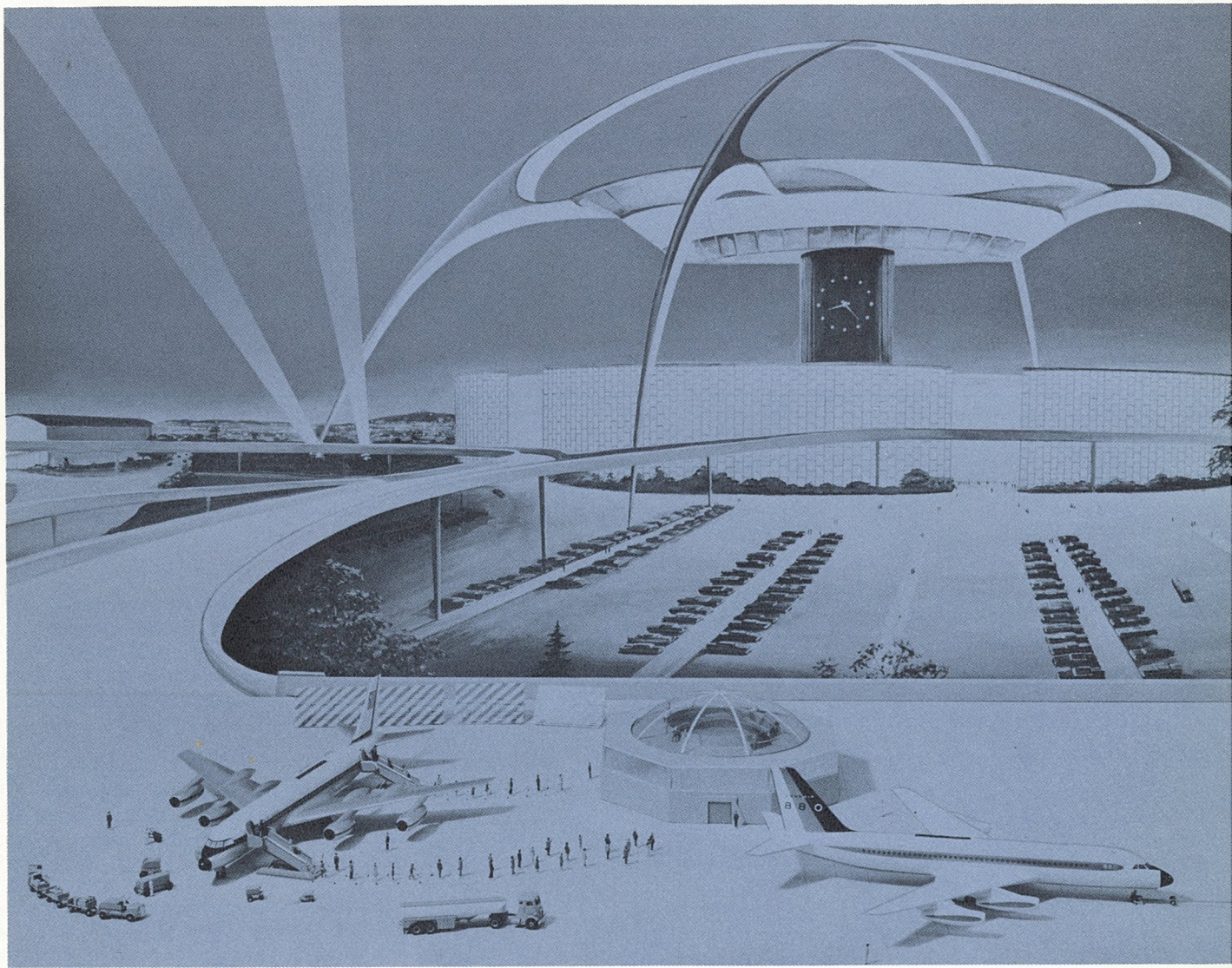


Carson

VOLUME XI NUMBER 1 MAY 1959

Convair Traveler



In this Issue: Engineering and Maintenance Training

VOLUME XI NUMBER 1 MAY 1959

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In this Issue: Engineering and Maintenance Training

OUR COVER

In at 7:58; out at 8:25! This short interval of time for a complete turnaround operation is clearly demonstrated by use of a diorama. Each item, an exact replica of the original, is scaled to 1/87 of the actual size. The diorama depicted is the proposed Los Angeles Satellite Terminal.

Convair Traveler

VOLUME XI

NUMBER 1

MAY 1959

MANAGER, CUSTOMER SERVICE — J. J. ALKAZIN
CHIEF, TRANSPORT SERVICE — L. J. BORDELON
CHIEF, SERVICE PARTS — J. DOIG
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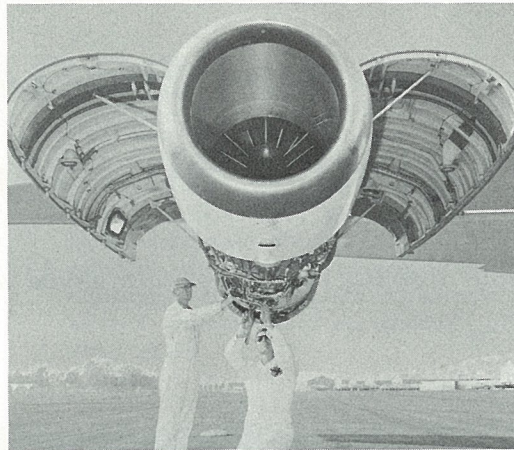
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R. K. Lawson

A digest of operation and service published monthly by the Service Publications Sections of Convair Customer Service Department in the interest of Convair operators. Communications should be addressed to the Manager of Customer Service Department, Convair, San Diego 12, California. Information is to be considered accurate and authoritative as far as Convair approval is concerned. FAA approval is not to be implied unless specifically noted. Recipients of this information are cautioned not to use it for incorporation on aircraft without specific approval of their cognizant organization.

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Wide doors on each CJ805-3 engine pod permit ready access to engine accessory and hot section compartments.

Convair 880 Pod permits fast servicing

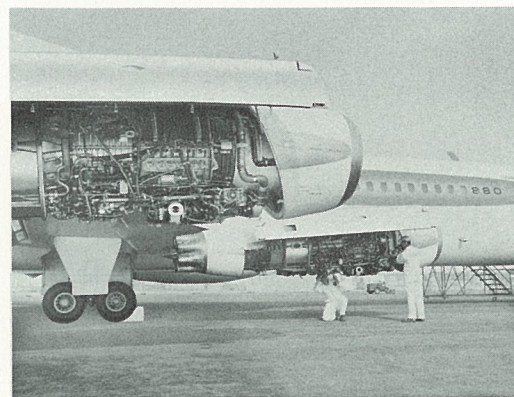
Ease of service and maintenance of the four General Electric CJ805-3 engines, which power the Convair 880 jet airliner, is made possible by wide, full-length pod doors exposing each side of the entire engine accessory and hot sections.

Hinged at the top edge, each door lifts upward to the fully open position permitting access to external engine components and accessories for inspection and adjustment within a minimum of time.

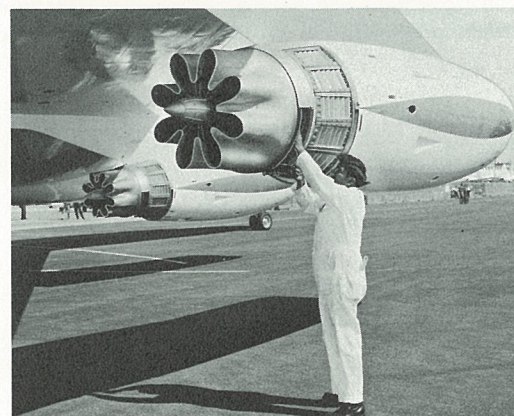
Structural members required to absorb slight lateral movement of the engine are integral with door construction, thus eliminating fixed structural members from the pod assembly, and thereby facilitating removal of engine and replacement of accessories and components.

Both inboard and outboard pod assemblies are at a convenient height to enable mechanics to perform inspections and adjustments.

Doors, with attaching spring clips, are provided within the large pod doors to permit emergency access of fire hose nozzles. Each left-hand pod door has a small access panel which may be used for draining the fuel-collecting cans. An access door in the No. 3 pod is for connecting a ground power cart to start the engine.



Both inboard and outboard pod assemblies are at a convenient height to enable ease of inspection and adjustment.

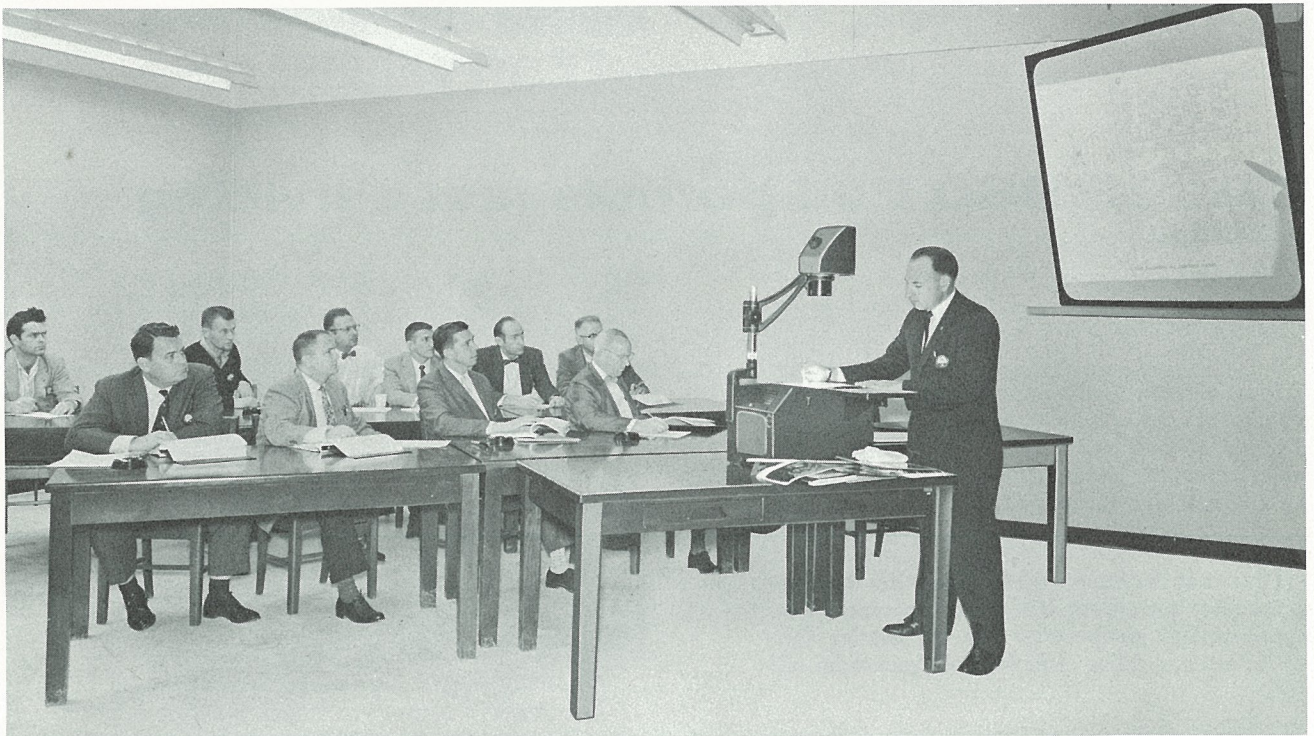


Access doors fair smoothly into streamlined pod assembly aft to sound suppressors and thrust reversers.

"600-880"

Engineering and Maintenance Training

"880" training program is formulated and administered by field service group



Classes are conducted in new air conditioned facilities, employing a variety of training aids, such as this projector and screen. The program is staffed by experienced, well-trained Field Service Representatives.

Maintenance begins with the preliminary design of a new aircraft configuration and continues as long as the aircraft remain in existence. Every item from the basic structure to the smallest operating unit is designed to give fail-safe and trouble-free performance. Detailed instructions are provided by Convair for operation of the various systems and components, and test equipment is developed to analyze the functioning of each unit. To insure that *all* related engineering and maintenance information is made available to the operator and that trained personnel are available for its dissemination, Convair has established an extensive customer training program.

The training program is being formulated and administered by the Field Service Group in the Transport Service Section of Convair. Physically, most of the training will take place in an area known as the "Customer Training Area" where complete new training facilities have been erected. Included in the area are classrooms, conference rooms, offices, a lounge, library, and all types of training aids.

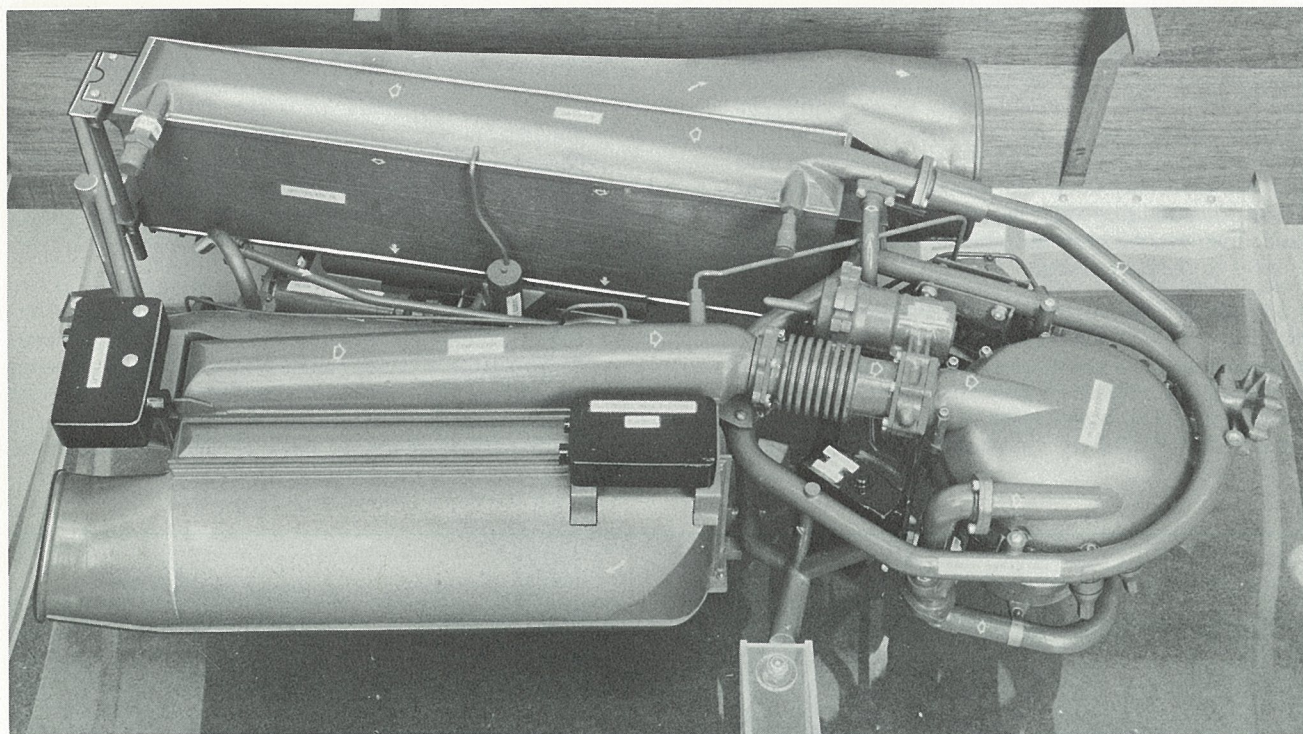
Customer Training will not be confined to this area, however. All portions of the plant are available if it is decided that a subject can be better illustrated elsewhere. In addition, Convair will dispatch a training team, together with appropriate training aids, to any geographical location if required by a customer.

A certain amount of customer training will also be provided by the Field Service Representatives at the various customer bases. One of the primary duties of these Representatives is to assist the operator in the establishment of his own maintenance training program. In addition, they may be called upon to personally conduct refresher courses for the operator's instructors whenever necessary. The Representatives are also responsible for disseminating new information pertinent to improved maintenance techniques and procedures.

The instruction given in the Customer Training Area will be of a more formalized type. The curricu-

of his supervisory and maintenance personnel through the entire course.

The first full length course of instruction has been scheduled for July. In attendance will be personnel from Convair's first 880 customer, TWA. This type of course will require up to six weeks to complete and will meet the requirements for maintenance instructors, key supervisory personnel, and line maintenance personnel. Comprehensive coverage will be provided on all subjects relating to servicing, ground handling, maintenance, and "trouble-shooting" of the aircraft engines, structure, systems, and associated components.



By study and inspection of mockups, such as this refrigeration unit for the air conditioning system, maintenance personnel become familiar with the Convair 880 before actually seeing or servicing it.

lum will be flexible however, and is designed to accommodate both supervisory and maintenance level personnel. Courses can be lengthened or shortened to fit the operator's needs, resulting in a "customized" training program.

Classes are normally limited to 20 students or less for individuality in instruction. Text content for each subject will be sufficiently comprehensive to give an understanding of the principal systems as well as related systems, components, and phases of operations. This will enable the operator to select the subjects that he requires for each particular group of students. Such latitude in choice will especially benefit the operator who, because of time or other reasons, cannot send all

The TWA full length course has been divided into four specialist classes to accommodate the different skilled groups established by the operator. The general headings of these classes are:

1. Line and Power Plant
2. Structure and Systems
3. Electrical
4. Electronics

Special orientation courses are also available for familiarizing airline personnel and others interested in the administrative aspects of Convair "600" and "880" systems, structures, performance, and ground handling. This coverage is intended to provide airline planning staffs with all the information needed for the

establishment of Convair "600" and "880" engineering and maintenance facilities. To portray this particular information, a large and colorful diorama has been constructed. Depicted is an airfield complete with terminal, aircraft, and all necessary ground handling equipment. Each item is an exact replica of the real thing, and all are scaled to 1/87 of the actual size. With such a panoramic display, it may be visualized how a Convair "880" can be completely serviced in only 23 minutes.

Other training aids besides the diorama intended for use in the training program are numerous animated and visual training aids, system mockups, transparency projections, in-plant production parts, "configurators," and the Burton-Rogers procedures trainer.

"Configurators" are small, individual note-book size reproductions of large, workable aircraft system diagram boards and were conceived by one of the Convair Field Service Representatives. Several different working configurations of a particular system can easily be illustrated with the use of these aids, and they are especially adaptable to the man in the field where other training aids are not available. A maintenance man can carry them in his note-book and study or refer to them as desired.

Sample parts used in the engineering design and production of "880" aircraft are sometimes brought to the classroom for study. One of these is a small version of the "880" wing. Like the actual wing in every detail, it is used to show the location of fuel tanks and operation of the fuel system in general.

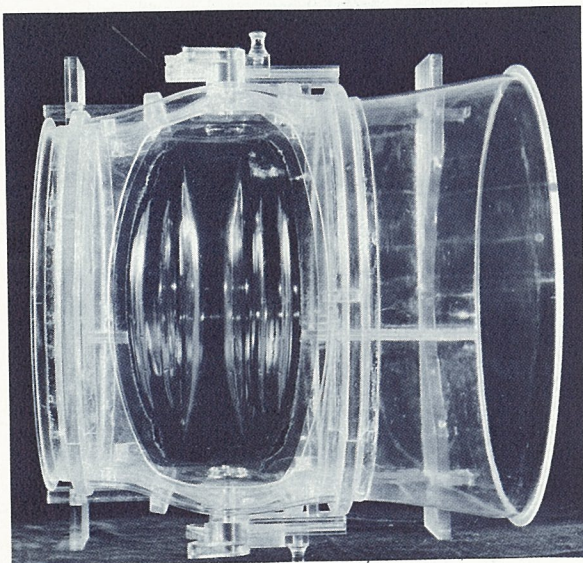
Aspects of structural design and the Scotch-Weld process can also be demonstrated by this type of aid.

The Customer Training Area includes a collection of more than 800 transparencies for projection in the classroom. Transparencies of schematics, flow diagrams, drawings, and photographs are used visually to supplement the instructor's explanation of the subject matter.

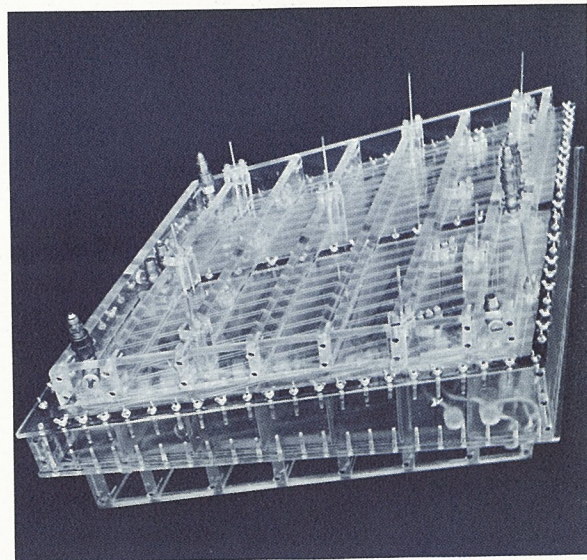
In order that some of the more complicated features of the "880" may be easily understood, certain training aids have been animated. Instead of drawings or schematics appearing alone on a static board, the systems or components in these drawings and schematics have been animated, or made to move in color. Information on the operation of a large and/or intricate mechanism, such as the flight control system, can be reduced to simple language by employing this aid.

For detailed study of some systems and components, mockups have been constructed. By study and close inspection of the mockups, engineering and maintenance personnel become familiar with their "880" and associated equipment before actually seeing or servicing it.

A recent innovation in the training program is use of the microfilm projector. Used heretofore at Convair in connection with the cataloging of spare parts, the projector is proving to be well suited for classroom instruction. Thousands of engineering drawings can be kept readily available for portrayal because of the small amount of storage space needed. Original draw-



Air flow through the variable stators in the engine compressor section is easily explained with an animated training aid such as this.



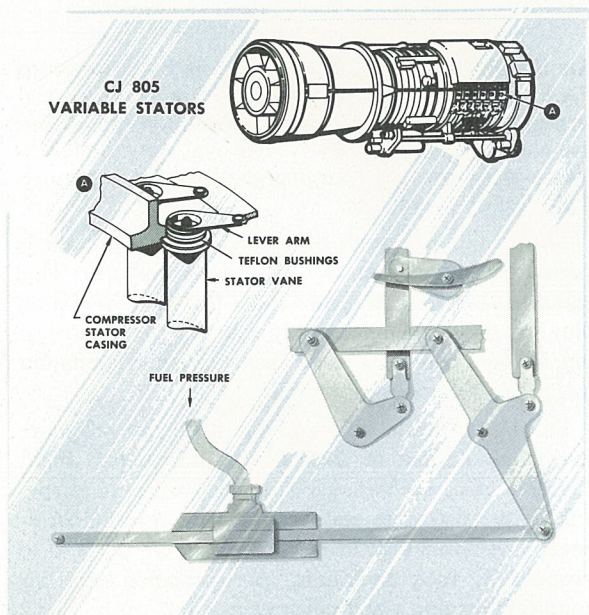
Operation of the fuel system can be traced in detail with this wing section from the test laboratory.

ings up to 42 inches in width and 12 feet in length can be reduced to the size of IBM cards; they can then be projected on the large screen of the combination viewer-enlarger-printer machine in the classroom and studied in detail. Quick prints of the microfilmed drawings may also be obtained from the machine for individual student study.

The biggest — and most expensive — training aid installed in the Customer Training Area is the cockpit procedures trainer which was manufactured by the Burton-Rogers Co. of Cincinnati, Ohio. An exact copy of the "880" cockpit, this trainer is to be shared jointly by Transport Field Service, Production Flight, and Flight Test in the training of pilots, flight engineers, and maintenance personnel. Instruments in the full scale model respond exactly as do those in the "880," enabling those concerned to become familiar with system operational procedures.

Forming the overall basis for "880" training are the Service Training Study Guides. These volumes cover both operational and maintenance aspects of the jet transport and are available to all customers. The Guides consist of five books which cover the following subjects:

1. Airplane General
2. Pneumatic Systems
3. Hydraulic Systems
4. Electrical Systems
5. Engine Systems



The manner in which thrust is reversed on CJ805-3 engines can be demonstrated with this training aid.

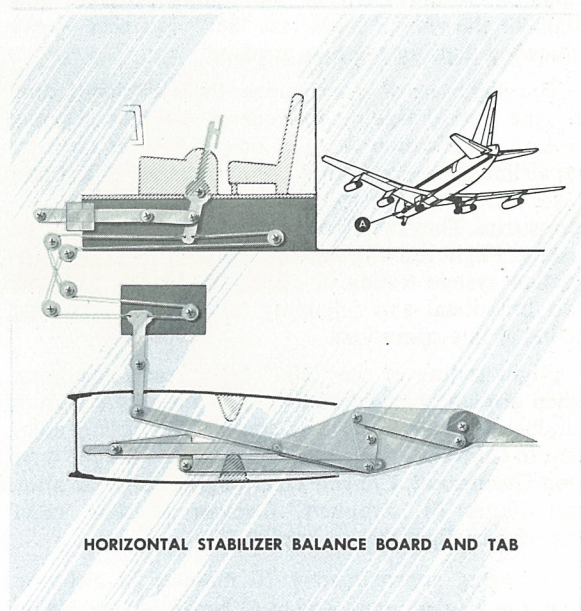
Convair has assembled personnel with many years of experience in dealing with operator field problems to act as instructors in the program. All of the instructors have served in the field as Field Service Representatives and have presented formal training courses. They will thus be "on the same frequency" as the students in their audience.

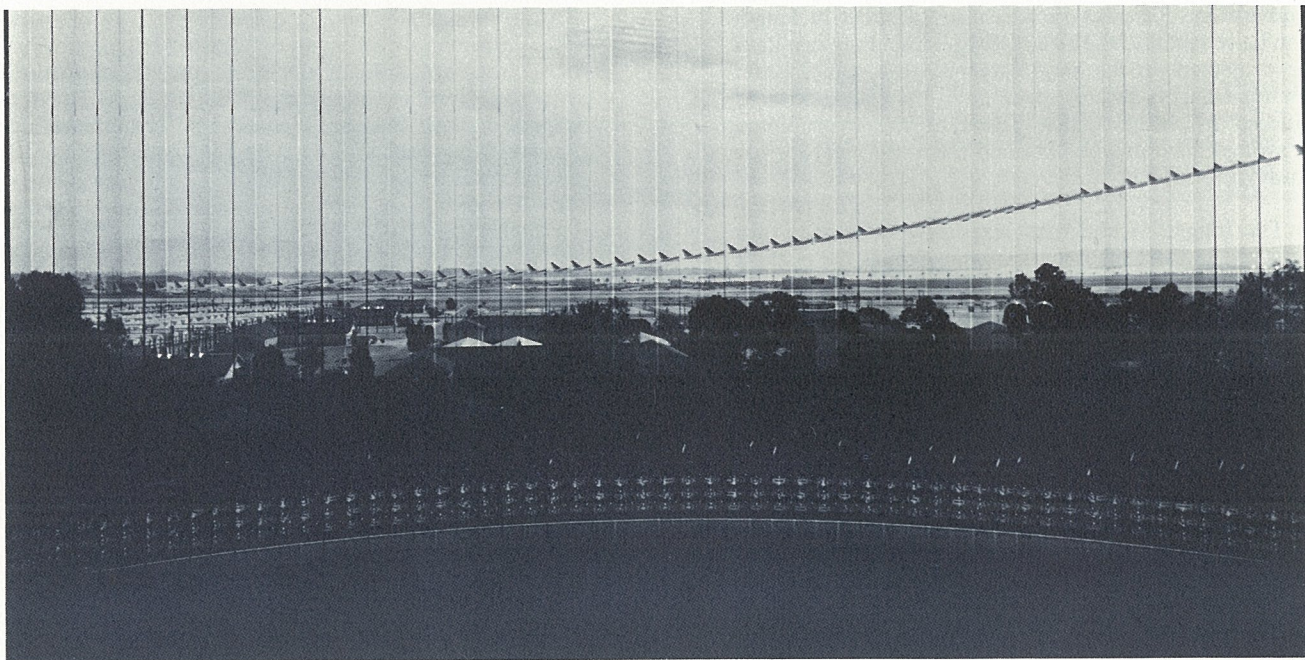
To insure that the instructors and students speak the same language and that the instructors are familiar with each minute piece of information covered, the Study Guides have been prepared by the instructors themselves. Each section of the text, plus associated training aids, has been individually prepared by the individual instructor selected to present that portion of the training program. These instructors also keep abreast of the latest design changes and day-to-day performance data resulting from flight tests and other sources in order that texts may be accurate and that any question arising from the floor can be immediately answered.

The experience of these instructors, coupled with their training aids and facilities, gives Convair an engineering and maintenance training program capable of rendering a valuable customer service.

Although jet transports may present some new engineering and maintenance problems, Convair's experience in building and maintaining F-102 and F-106 jet interceptor aircraft and over 1,000 Convair-Liners will serve as an excellent foundation for conduct of Convair's "880," and later Convair's "600," maintenance training programs.

Movable parts in this animated training aid indicate how certain elements in the "880" flight control system operate.





A Convair 880 jet airliner takeoff is shown in upper portion of picture. Vertical lines show airplane each 1.7 degrees of motion. Elapsed time in seconds and microseconds is shown at bottom of picture. Enlarged prints are used to study takeoff and landing performance.

Convair 880 Flight Test Program

recording—telemetry—data reduction expedite "880" flight test program

Convair flight testing evaluation of the "880" jet airliners is ahead of schedule. A factor which has precipitated advancement of the testing program was flight of the second flight test "880" just nine weeks following flight of the first airplane.

The flight test program utilizes three airplanes, during the period leading to Federal Aviation Agency (FAA) certification of the Convair 880 jet airliners for airline operations. Flight test airplanes No's. 1 and 2 are extensively instrumented, and are without interior trim. They are used for most of the basic systems testing. Flight test airplane No. 3 is scheduled for production system testing of air conditioning, acoustics, and functional and reliability test flights simulating actual airline operations.

Flight testing of the "880" began early this year, when airplane No. 1 was flown, on January 27, from Lindbergh Field, San Diego commercial airport adjacent to Convair. At the controls on the first flight were Don Germeraad, Convair chief engineering test pilot, and Philip M. Prohett, Convair assistant chief engineer of flight test, as copilot.

Following approximately 76 minutes of airborne time, the airplane was landed at North Island, Naval

Air Station, San Diego, where it was based prior to FAA approval for flight operation from a commercial airport. After 11 hours of flight operation time, from the Naval Air Station, FAA approval was granted to return the airplane to Lindbergh Field for continued flight testing operations.

Nearly 6,000 pounds of special instrumentation is contained in the first two flight-test airplanes. This equipment is used to record flight test information on film and magnetic tape, and to transmit, by telemetry, in-flight control surface displacement information to a ground monitoring station.

During the initial stages of the flight test program, tests were limited to shakedown and general flight characteristics evaluations. Following were more specific tests relating to stability, control, and performance. Additional tests in the program were devoted to propulsion, fuel, hydraulic, pressurization and air conditioning, and electrical systems.

Each phase of in-flight control surface displacement testing was simultaneously reproduced on direct-writing recorders in the Convair telemetry ground station. The analyzed results were promptly relayed



Remote ground-located takeoff and landing performance camera is shown filming takeoff of Convair 880 jet airliner. Camera mechanism frames airplane each 1.7 degrees of motion. Digital counters record elapsed time in seconds and microseconds.

to the airplane crew. Testing then proceeded to the next step as rapidly as satisfactory results were obtained.

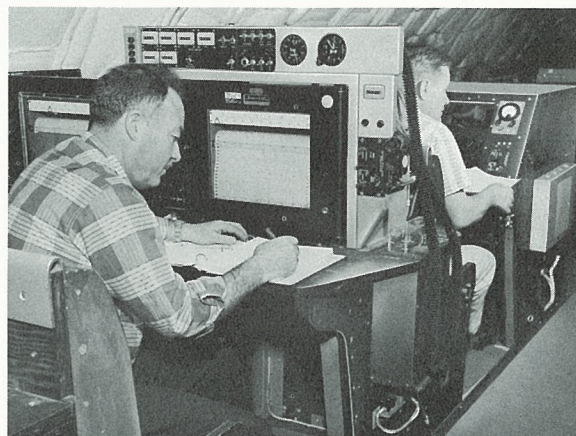
A remote ground-located takeoff and landing performance camera was used to record rate of acceleration and climbout performance during takeoff. Digital counters in the camera mechanism recorded the airplane each 1.7 degrees of motion, giving time in seconds and microseconds. Prints were then enlarged for study of the action recorded.

Data cameras, installed in the airplane, recorded instrument readings to provide accurate data as a basis for evaluation of aerodynamics and system performance for each phase of the flight testing program under study.

The special airplane telemetering instrumentation and the equipment at the ground station are geared to simultaneously transmit and record 20 channels of analog information. The ground station crew and the airplane crew maintain two-way voice communication throughout each telemetered flight.

Simultaneous recording, transmission, and ground monitoring of in-flight test information materially expedited the flight test program by enabling progression to the next phase of testing without concluding each flight for lengthy data reduction.

A few of the tests so far concluded, or in progress, are powerplant operation; emergency landing gear operation; emergency fuel jettisoning; airspeed calibration; control surface displacement; and airplane performance.



Engineers monitor in-flight performance from instruments in fuselage of Convair 880 jet airliner.

Operating characteristics of the General Electric CJ805-3 engines were thoroughly checked out in flight, for both normal and emergency operating conditions. The engines performed smoothly and effectively under punishing handling with the throttle, consisting of sudden acceleration and deceleration under varying conditions of flight. Engines were also shut down and restarted in flight without incident.

Emergency fuel jettisoning was satisfactorily evaluated. Fuel streamed from the nozzles, six feet inboard from the wing tips, cleanly away from the airplane, without impinging on the wings or tail during the jettison test.

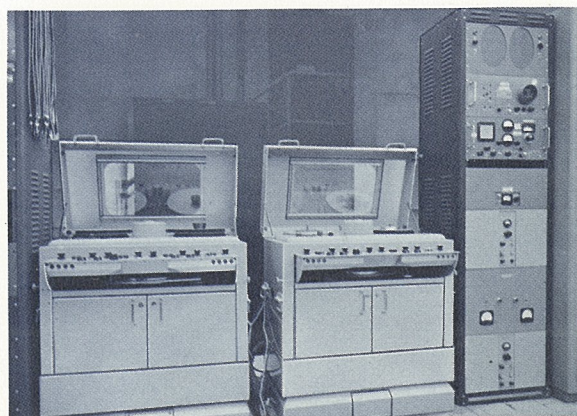
Airspeed calibration to check the airplane airspeed position error was successfully performed, using a trailing airspeed bomb as a calibrated static source reference. The bomb was released through one of the cargo compartment doors, and retrieved without difficulty.

Tests of the airplane control surfaces were conducted with surface shaker mechanisms to induce displacement of the surfaces at varying amplitudes and frequencies, so as to determine if the control surfaces demonstrated satisfactory damping capabilities. Pilot-induced control surface displacement was also used in these tests.

Accelerometers and control surface position indicators transmitted the displacement impulses to recording and telemetering equipment, in the airplane fuselage, which recorded and transmitted these data to the ground station.

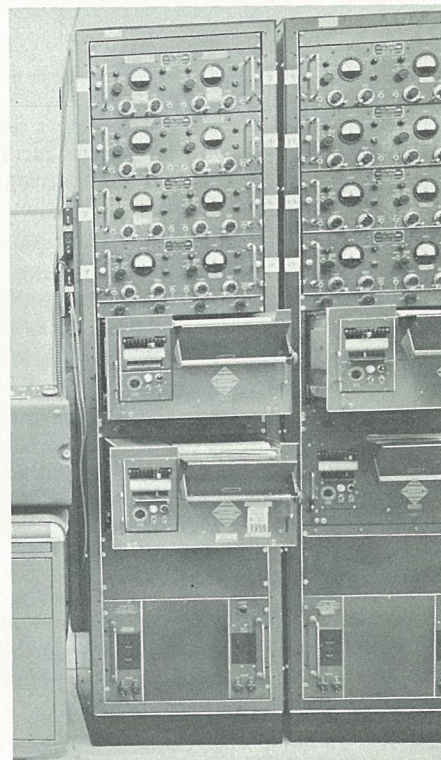
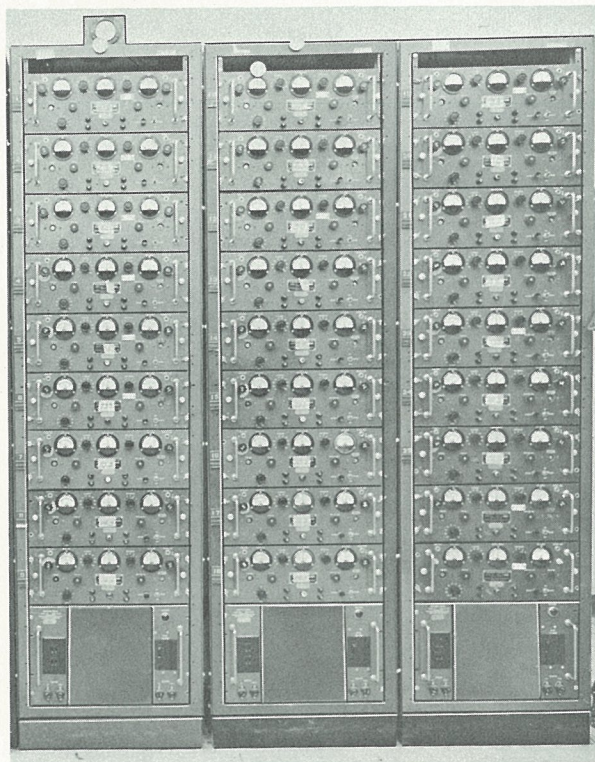
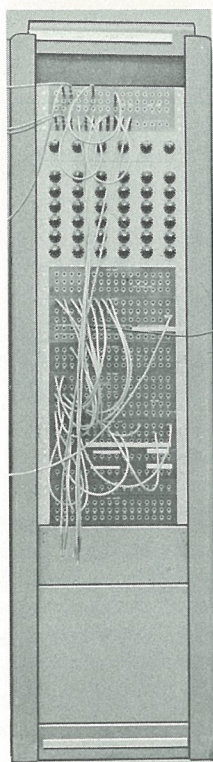
Shakedown checks of the airplane systems and qualitative stability and control runs through a wide range of speeds up to an altitude of 40,000 feet are completed. Stability and control were satisfactory through the range tested. Cabin pressurization was checked out and has been used on most flights.

The Convair 880 jet airliner has successfully proved speed capabilities of Mach 0.93, a maximum indicated



FM/FM telemetering receiver (right) in Convair ground data station detects composite signals from airplane. Composite signals are recorded on magnetic tape recorders (left).

airspeed of 430 knots, and approximately 650 mph true airspeed. The airplane has also successfully proved its ability to operate as a medium range transport, with long range capabilities, at near maximum design takeoff weight, within the limitations of most airport runways designed for four-engine, propeller-driven aircraft.



Patch panel (left) routes composite signals from receiver to discriminator (center). Discriminators sort individual signals from each end pickup on airplane control surfaces. Signals are returned to patch panel for routing to direct-writing recorders which trace analog curve showing amplitude and frequency of airplane control surface displacement.

New Type Adjustable Harness Board

for more than 30 miles of electrical wiring in the Convair 880-600

Universal type peg board fixtures, on which duplicate electronic and electrical wiring harnesses can be assembled, went into production with the first Convair 880 jet airliner. The new fixture possesses a versatility that permits 865 different "set-ups" on each fixture, or combination of fixtures, to accommodate the more than 30 miles of wiring installed in each production "880."

This versatility is achieved by means of removable pegs, which can be relocated in any of 4884 one-eighth inch holes drilled on five-eighths inch centers to fit any harness configuration needed for a particular set-up. The new fixtures measure two feet by eight feet, and are constructed of one-half inch plywood. They will replace several hundred of the old permanent peg type fixtures, and result in a saving of some 1,600 square feet of floor space required to store the old type fixtures.

The new peg board fixtures are indexed numerically along the top and bottom, and alphabetically along each side. An alphabetically lettered "T" square is used to accurately locate peg positions with the numerical and alphabetical indexing, when the fixture is set up for fabrication of a harness assembly. The fixture set-up is made from a permanent photographic record of a previous harness assembly mounted on the fixture.

A full-scale metal mockup of the "880" airplane was used in the fabrication of each initial harness assembly. Working from engineering circuit and connection diagrams and from engineering harness prints, each wire was fitted into the mockup to determine precise length, breakout, and splice area. Small items of equipment, including gages, switches, relays, and terminals were installed, and the finished harness or harness section assembly was completed.

This harness assembly was then removed from the mockup and attached to the new universal peg board fixture in the nearest possible configuration in which it would later be installed in a production airplane. A part number, by which all future identical harness assemblies would be identified, was affixed to the upper right hand corner of the fixture. Charts were attached to the fixture to identify all wire sizes, breakouts from the harness, and to show the attaching part or wire terminal connection by part number.

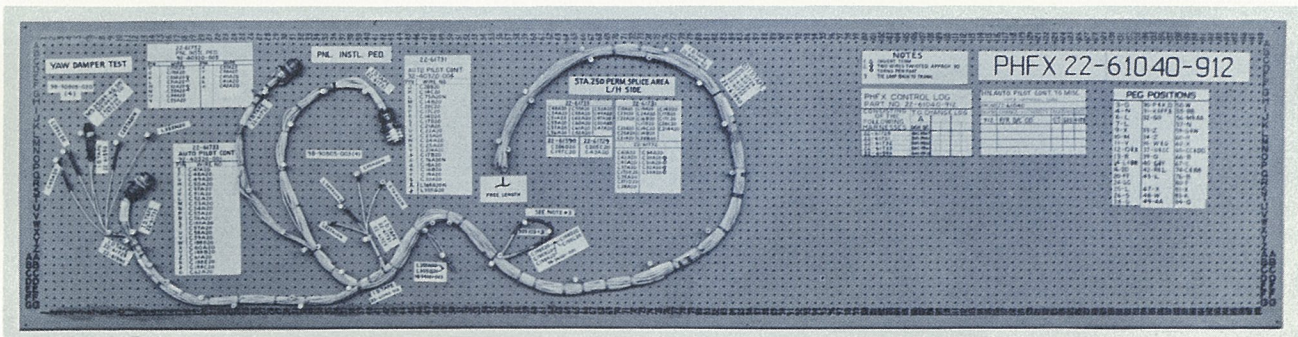
A chart, showing the peg positions for this particular harness assembly, and notes of special significance were attached. A control log, for entry of any future changes which might be made to this harness assembly, and an inspection stamp-off chart were also attached to the fixture.

When the harness assembly and all pertinent data necessary for the fabrication of an identical harness assembly were completed, the fixture was moved to the photo area where a permanent photographic record was made on indestructible Cronaflex film, after which the harness assembly, part number, charts, and other data were then removed from the fixture.

One copy of the Cronaflex film record, and all charts from the fixture are filed in the assembly department under the harness part number. Two copies of the Cronaflex record, all circuit and connection diagrams, and the harness print are filed in the proof-planning department, where production scheduling and control of future changes or alterations to this particular harness assembly are maintained.

In addition to the storage space saving achieved with the use of the new universal peg board fixtures, the outstanding advantage is in the fact that an absolutely identical harness assembly can be fabricated from the Cronaflex record, to fill additional production or spare parts orders within a minimum of time.

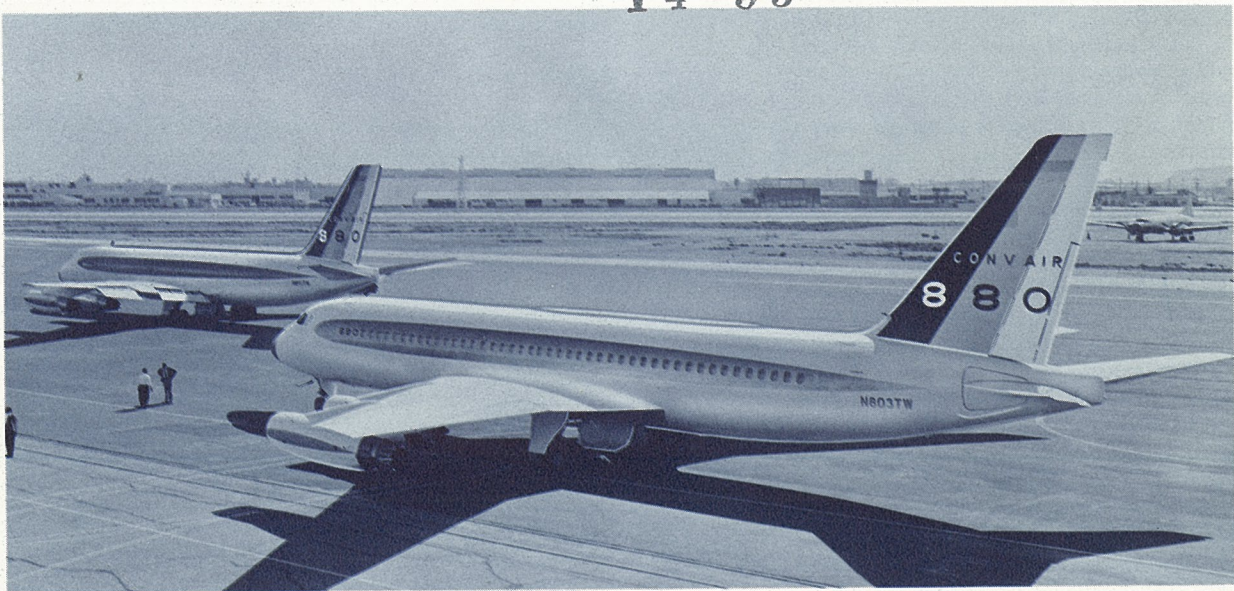
14 53



Adaptability of new universal peg board fixture facilitates fabrication of electrical and electronic harness assemblies. Board shows complete information necessary to select wire sizes, lengths, and terminal fittings. Splice areas, terminal equipment, inspection stamp, peg positions, part number, and special notes pertaining to harness are also shown.

Convair 880 jet airliners, No's. 1 and 3, are photographed immediately outside the final assembly building following factory completion of No. 3 airplane. The Convair 880's, world's fastest (615 mph) jet airliners, are scheduled for airline service in early 1961.

14 53



First flight of the No. 1 "880" occurred on January 27. No. 3 joined her sistership in the flight testing program nine weeks later on March 31. Many phases of the "880" flight test program have been expedited with the use of two airplanes.

Airplane No. 2 is currently undergoing proof load testing in the Convair Structures Laboratory. Airplane No. 4, the first with completed interior, will be used in the flight test program to simulate actual airline operations.

CONVAIR SAN DIEGO

CONVAIR DIVISION

GENERAL DYNAMICS CORPORATION

VOLUME XI NUMBER 2 JUNE 1959

Convair Traveler

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In this Issue: Convair 880/600 Hydraulic Systems

OUR COVER
Servicing speed and efficiency were prime objectives in design of Convair's jet airliners. This flight-test "880" has been refueled and fully checked out in record time. Only ground cart combustor and a-c power cart are still standing by, readying for engine start.

VOLUME XI NUMBER 2 JUNE 1959

Convair *Traveler*



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HYDRAULIC SYSTEMS
Hugh R. Smith

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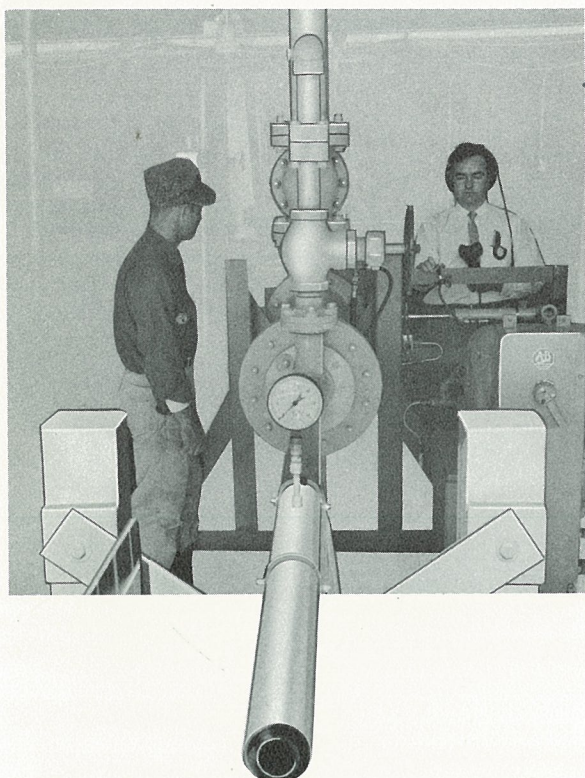
BIG JOB FOR TEFLON
Hugh R. Smith

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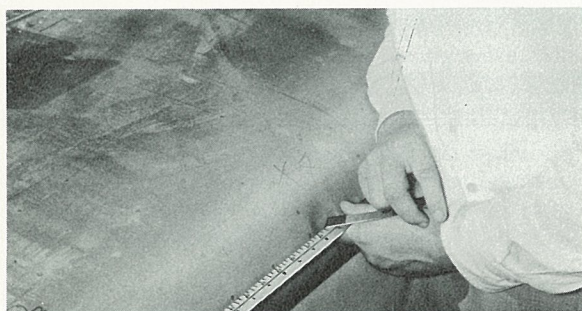
Hailstone Tests

... prove the Convair 880 wing leading edge skin can take it ...

What are believed to be the first "hailstone" tests ever conducted in connection with the development of a high speed jet transport were held at Convair-San Diego to evaluate the structural integrity of the Convair 880 jet airliner wing leading edge. Not only did the leading edge come through the tests with a "whole" skin, but relatively minor dents constituted the extent of the damage.



Looking into the "business end" of Convair's "ice cube" gun, used to bombard Convair 880 wing leading edge during hailstone tests.



Deepest dent ($\frac{3}{8}$ " in "880" wing leading edge following hailstone tests proves structural integrity of heavy gage (.051) aluminum skin.



Man-Made hailstones are displayed in halved rubber balls and egg cartons used to freeze to desired density and hardness for ammunition.

Three commercial products, far removed from the aircraft industry, were used in the manufacture of the "man-made" hailstones. The kitchen blender served to pulverize ice cubes; the resulting snow was packed into halved rubber balls for molds; the rubber balls were placed in egg cartons; and the cartons put into a shop-type rivet freezer until they reached the desired density and hardness. Made in two sizes, the finished products were $\frac{3}{4}$ - and $1\frac{1}{4}$ -inch diameter balls of ice.

The balls of ice, simulating hailstones, were "fired" from a high speed air gun against the heavy gage (.051-inch) aluminum alloy skin of the wing leading edge. Results of the tests revealed that the skin yielded only $\frac{3}{8}$ -inch maximum depth in any area from the impact of a hailstone.

The high speed air gun consisted of a smooth bore steel tube mounted inside another steel tube, with a clearance between the inner tube "barrel" and the outer tube, and a breech chamber into which the compressed air was introduced.

The hailstones were muzzle-loaded in the barrel and fired by means of high pressure air, bled from the Convair high speed wind tunnel tanks, at a pressure of 120 psi. The breech chamber of the gun was designed to allow simultaneous passage of air into the space between the barrel and the outer tube for the purpose of simulating aerodynamic qualities of flight during the firing of the hailstones.

Sudden release of the compressed air into the breech chamber of the gun propelled the hailstones at speeds up to 575 mph, a speed greater than the Convair 880 will encounter during thunderstorms, because pilots avoid thunderstorms, if possible, or reduce speed consistent with air turbulence when structural damage to the airplane may be incurred.

A six-year survey has revealed that hailstones larger than one inch diameter do not occur more frequently than once in every 800 thunderstorms. Although the probability of encountering hailstones of $1\frac{1}{4}$ -inch diameter is slight, design of the Convair 880 wing leading edge skin has proved the structural integrity necessary to withstand such punishment, without incurring enough damage to affect aerodynamic stability.

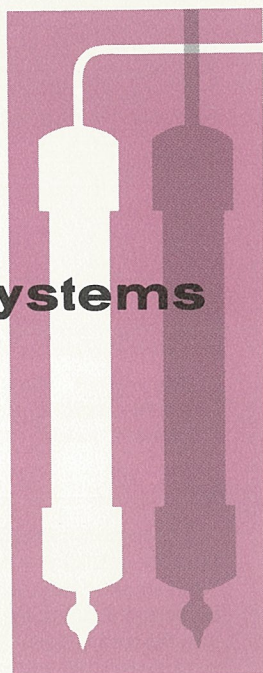
Hydraulic Systems

Convair

880

and

600

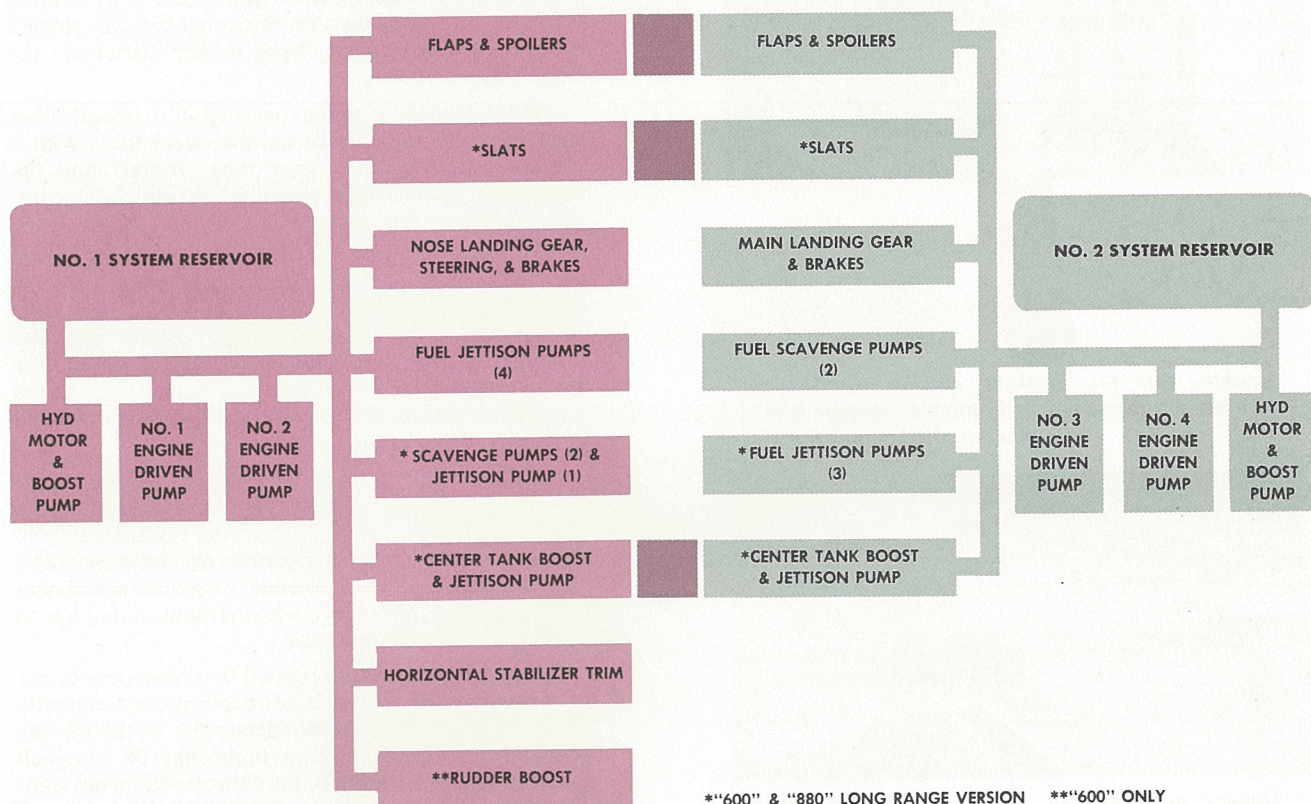


There are major differences between hydraulic systems of the new Convair jet airliners and those of Convair-Liner type aircraft. Where a Convair 440 has one main system and an auxiliary pump, the "880" and "600" have two complete, independent systems, with an auxiliary pump for ground operations.

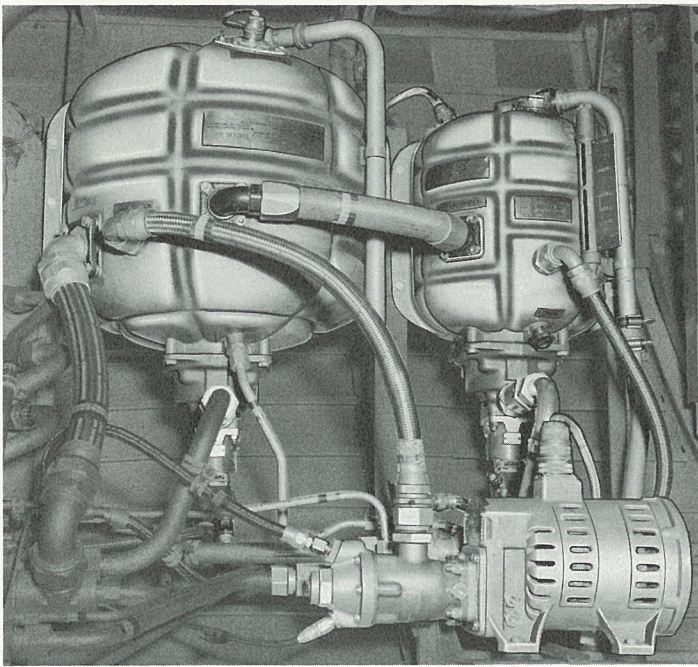
A second difference is in relative sophistication of hydraulics in the jet transports. In most piston-engine aircraft, the main hydraulic system is used only intermittently, principally during takeoff and landing. In the "880," hydraulic power is used more or less constantly during flight for servo operation of the spoilers and stabilizer trim. Hydraulic motors defuel the tanks, airborne or on the ground, and, in the "600," hydraulic actuators supply rudder boost. Demands are not only extensive but the systems require the utmost in efficiency and reliability.

In the Convair jet transports, both No. 1 and No. 2 systems are 3000-psi, closed-center systems, each powered by two engine-mounted pumps. Both systems operate flaps and spoilers, and also the slats on the larger gross-weight versions. The No. 1 system operates the nose landing gear, including steering and brakes, and horizontal stabilizer trim. The No. 2 system operates the main landing gear, including steering and brakes, and horizontal stabilizer trim.

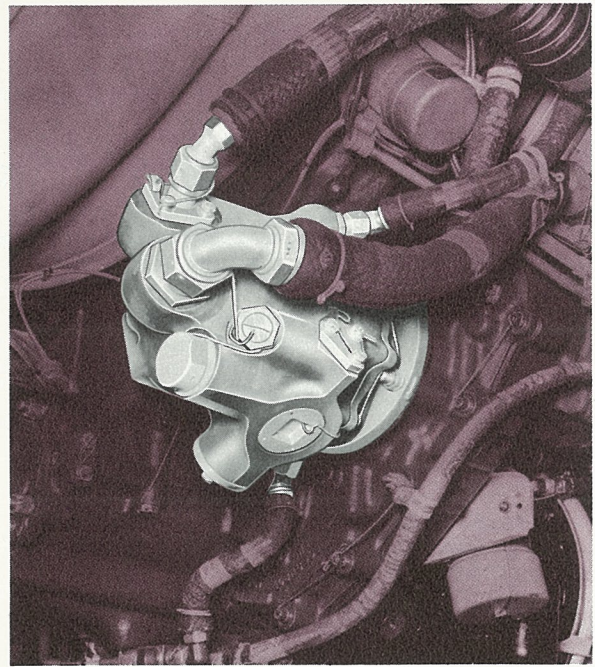
Two independent systems meet new standards of performance and reliability in Convair's new jet airliners



Hydraulic System Block Diagram



View from compartment door shows No. 2 and No. 1 reservoirs (left and right respectively), supply pumps (below reservoirs), auxiliary pump.



One main hydraulic pump is mounted on each engine on forward face of forward (transfer) accessory drive gearbox, just left of the starter.

system operates main landing gear and brakes. Operation of fuel jettison and scavenge pumps is divided between No. 1 and No. 2 systems. The auxiliary pump supplies power to operate either of the main systems. For emergency main gear door extension and braking, large-capacity accumulators and an airflask provide high-pressure air storage.

Hydraulic fluid is Skydrol 500, a fire-resistant phosphate-ester chemical, currently considered the best of the hydraulic fluids available. Since it dissolves or softens many sealants and finishes, aircraft using Skydrol must be designed for it. Interior pod-pylon finish, for example, is Skydrol-proof as is the Scotch-Weld prime coat and the Scotch-Weld in the wing. Hydraulic hoses are Teflon-lined, and all valve and actuator components are of materials unaffected by Skydrol.

Reservoirs and ground connections are located in a compartment aft of the main wheel wells. The reservoirs are interconnected, so that they can be filled simultaneously from one point. The No. 1 system reservoir has a gravity filler neck and a remote pressure fill connection. Interconnect line fittings are located at a level so that a leak in one system will not cause depletion of the fluid in the other.

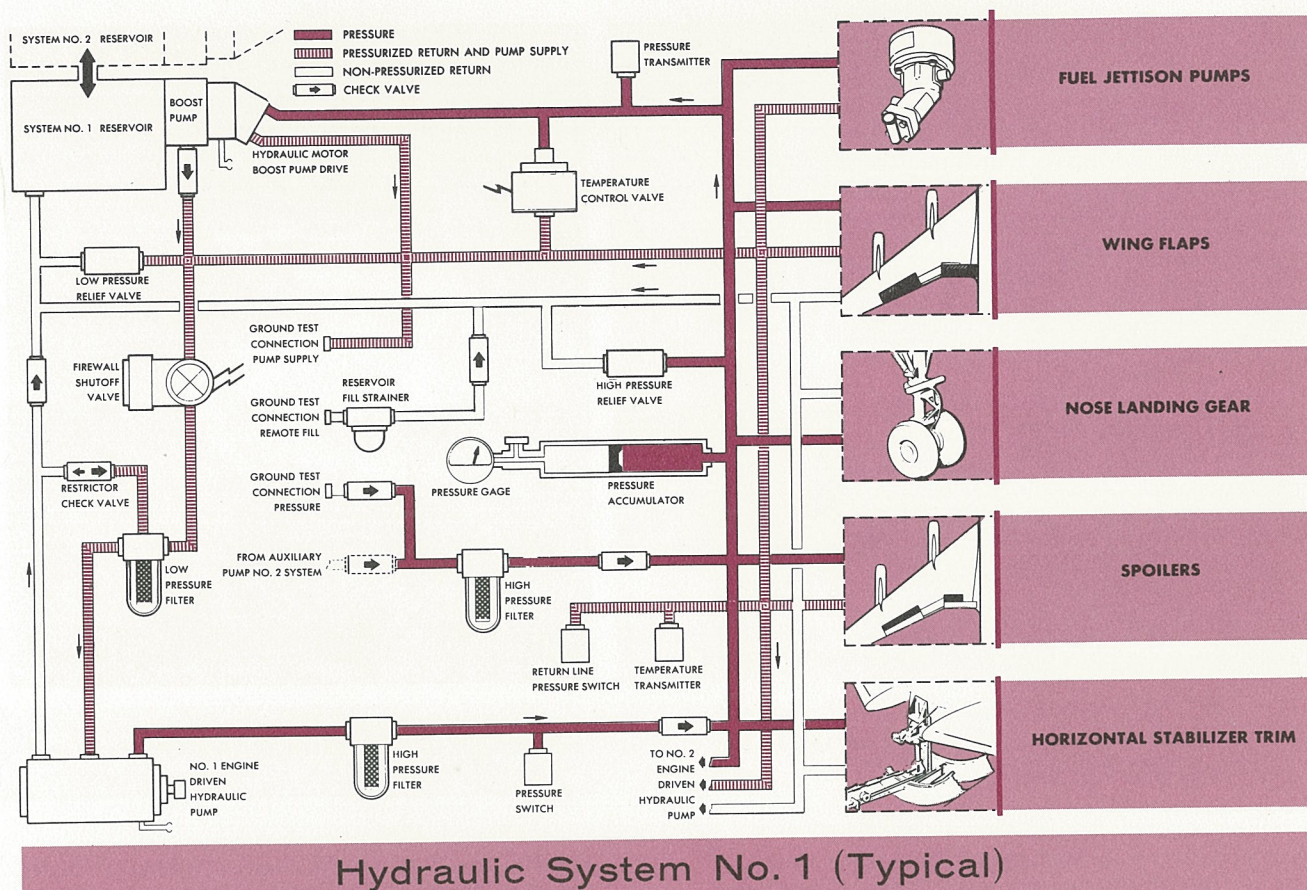
Pressure and supply line connections for ground test and operation, and the reservoir filler connection are just forward of the hydraulic compartment access door. A sight gage on No. 1 reservoir is marked FULL and REFILL for three conditions — systems and accumulators under full pressure, systems and

accumulators with zero pressure, or pressure only in the main landing gear system (downstream of the MLG check valve). Fluid quantities can also be read on the flight engineer's panel. The No. 1 reservoir holds approximately 2½ gallons, the No. 2 reservoir approximately 8½ gallons.

Each reservoir is vented to the compartment, which is maintained at cabin pressure. The low surface pressure is a factor in preventing air entrapment. At each reservoir outlet is a variable-delivery vane-type boost pump, operated "bootstrap" fashion by hydraulic motors powered by the 3000-psi system. The pumps maintain a normal pressure of 70 to 80 psi in the supply lines to the engine-mounted pumps.

At each pylon, the engine supply line is routed through a firewall shutoff valve and a filter. The shutoff valve is operated by a d-c motor, controlled from the flight compartment by switches on the flight engineer's panel.

One main hydraulic pump is mounted on each engine on the forward accessory drive gear box. No. 1 system pumps are on the two left-hand engines, No. 2 pumps on the right-hand engines. The pumps are radial-piston variable-displacement type. That in the "880" (the "600" pump is larger) has a flow capacity of 6 gpm at 1500 rpm and 16 gpm at 3750 rpm. Each pump contains a rotor with 21 cylinders in three staggered rows, each with a free-position piston. Surrounding the rotor is a track and support ring assembly; flow is controlled by shifting the assembly to vary the piston stroke. The control mechanism is



a hydraulically-operated servo pressure unit. A shear section in the pump protects against major damage from a malfunction that might cause a sharp rise in system pressure.

From the pump, fluid flows through a high-pressure filter in the pylon. The low-pressure and high-pressure filters are mounted close together, with access openings to allow quick inspection. These filters (on the "880" only), as well as the auxiliary system filter in the hydraulics compartment, have a red pop-up button. When pressure across the filter drops more than a specified amount, the button projects until the red is visible, and remains out until manually depressed. It is thus possible to tell at a glance when a filter needs servicing.

Each system high-pressure line returns to an accumulator in the hydraulic compartment. This is precharged with dry air or nitrogen to a pressure usually $\frac{1}{4}$ to $\frac{1}{3}$ of system pressure; it serves as a reserve supply of fluid for sudden system demands, and also for dampening pressure surges.

Both high- and low-pressure lines have pressure relief valves to dump excessive pressure to return lines. In the "880," in the low-pressure line to each engine, is a restrictor-check valve. The restrictor allows a constant flow of 1 gpm from the filter to the unpressurized

return line and serves to remove any accumulation of entrapped air in the filter. The check valve serves several purposes. It is an alternate filter bypass to ensure a supply of hydraulic fluid to the pump. Because the pump case drain line is routed by this valve, it allows circulation through the pump when the firewall shutoff valve is closed. Also, it eliminates pump knocking caused by excessive pressure differential during engine start or slow speed operation.

In each system high-pressure line is a solenoid-operated temperature control valve. This can be opened by the flight engineer to raise fluid temperature by recirculating from high-pressure line to pump supply line. The valve is not normally used unless fluid temperature falls below 0°C . Radiation and convection from the airplane's 300 feet of lines keep fluid temperature well below system limitations.

The auxiliary pump is a variable-displacement pump, driven by a three-phase 115/200-volt motor. It draws fluid from the larger No. 2 reservoir through a suction port located at approximately the reservoir interconnect line level, so that it will not empty the No. 2 reservoir in the event of a leak in the No. 1 system. Output is to both No. 1 and No. 2 pressure lines through high-pressure filters. The ground pressure line utilizes the same filter. A check valve is installed upstream from the auxiliary pump line con-

nection to prevent motoring of the pump from the ground cart. Another check valve is installed downstream from the filter, to shut off main pump pressure from the auxiliary system.

On the ground, the auxiliary pump can provide hydraulic pressure for operating system components. It must be on to prime the engine pumps prior to engine start and may be used to check out the controls and to pressurize the accumulators.

HYDRAULIC OPERATION OF FLIGHT CONTROLS

Each of the three spoiler sections in each wing (one inboard and two outboard) is raised by a pair of piston actuators, one for each hydraulic system. Two dual servo valves in each wing, one for inboard and one for outboard spoilers are operated by pushpull linkage from the aileron-spoiler mixer at the airplane centerline. A followup mechanism stops servo valve flow when the spoilers reach the position set by the pushpull linkage. On one hydraulic system, spoiler hinge moment is reduced but actuating speed is the same.

If aerodynamic pressures are too strong, hydraulic pressure can leak back through the servo valve permitting some blowdown. Further blowdown causes the

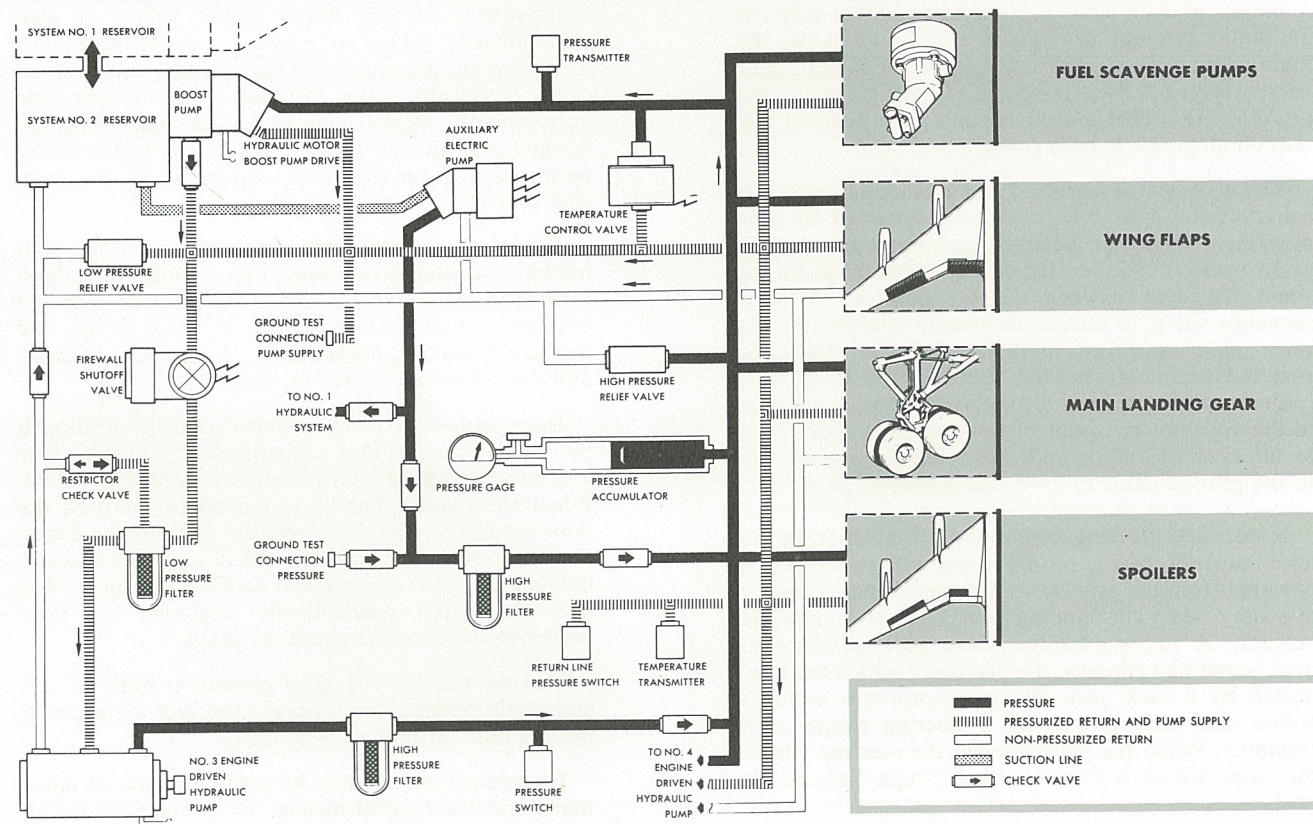
followup linkages to open the servo valve, and the extra hydraulic pressure generated by the air loads will be relieved.

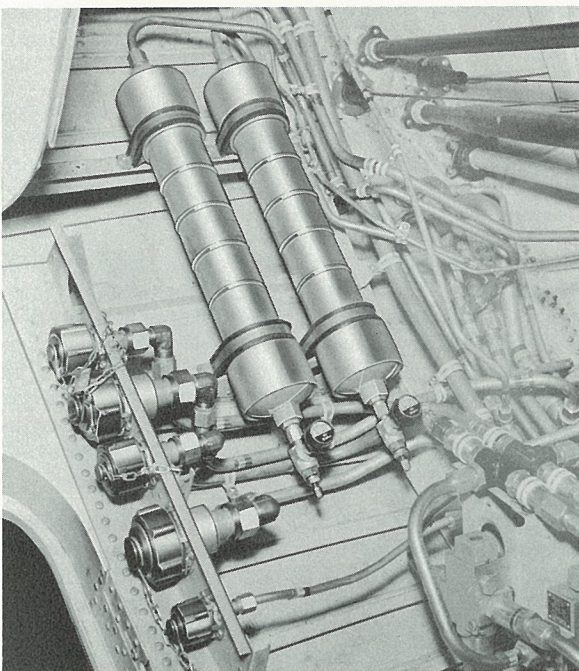
Flaps are actuated by recirculating ballbearing screwjacks, driven by high-speed torque tubes from a gearbox at the airplane centerline. The gears are planetary type and are driven by two hydraulic motors, one for each hydraulic system.

The flap motors are governed by a selector valve, controlled by cable linkage directly to the flight compartment. To prevent asymmetric flap extension, flow to the hydraulic motors can be cut off by an electrically-actuated dual shutoff valve, controlled by rotary switches at the outboard ends of the torque tube. If the switches are out of phase from asymmetric rotation of the torque tubes, power is cut off from the flap motors.

The leading edge of the "880" horizontal stabilizer is moved up and down by a traveling nut on a screwjack. The nut is turned by a worm gear driven by a hydraulic motor. Power is metered by a selector valve mounted on a followup screw. Followup screw rotation is controlled by cables to the flight compartment trim wheel. The stabilizer mechanism of the "600" aircraft is of a different design and will be discussed in a future Traveler.

Hydraulic System No. 2 (Typical)





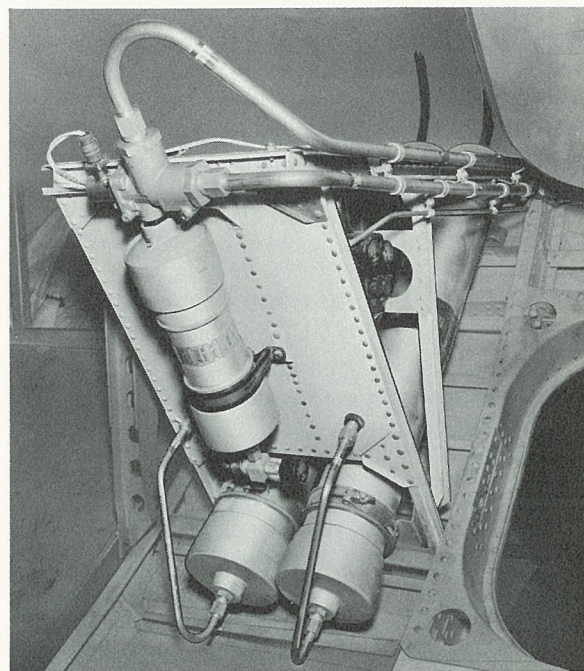
System accumulators and ground test panel are forward of access door. Four connections are for pressure and supply lines; lower is filler line.

LANDING GEAR

Nose and main landing gears, being in two different hydraulic systems, are linked together only in the flight compartment control linkages. The landing gear control lever has three positions, UP, NEUTRAL, and DOWN. NEUTRAL is the normal flight position and cuts off all power to both gears.

The nose gear is retracted and extended by a piston actuator; the door is mechanically operated by gear movement. The gear is locked up by hydraulic action of an uplatch cylinder, tripped by mechanical means when the gear reaches the up position. A door sequence valve, in turn mechanically operated by the gear uplatch cylinder, locks the doors up when the gear is latched. Moving the selector valve to DOWN position, ports pressure through a priority valve, first to the *door* uplatch cylinder to release the door; then, to the *gear* uplatch cylinder to release the gear; and to the gear actuator to lower the door and gear.

Nose wheel steering, controlled by cables from the nose steering wheel in the flight compartment, is powered from the gear-down line, and hence is operative only when the landing gear lever is in DOWN position. A steering control valve ports pressure to dual actuating cylinders, the pistons of which are connected by a rack gear. The rack moves a segment pinion gear that is part of a steering torque arm assembly. When the pilot releases the steering wheel, the nose wheel is free to caster, regardless of its position.



Pair of accumulators, aft of access door, are for MLG operation. Third cylinder is the pressure modulator in the Hytrol anti-skid brake system.

The main gear hydraulic system, including brake lines, is isolated by a check valve in the pressure line. Downstream of this MLG check valve are two accumulators, joined by tubing, to assist the pumps in making up the pressure drop caused by gear retraction. A priority valve between pressure line and accumulators restricts flow to the accumulators when landing gear system demand is greatest, and opens to permit flow from the accumulators when line pressure drops beyond a certain point.

The MLG selector valve contains spools for both normal and emergency operation. Normal actuation is through two sequence valves, one for each gear and one for each door. With gear up and door closed, and the gear handle in NEUTRAL, all gear and door *up* and *down* lines are vented to return.

Door sequence valves are mechanically positioned by gear uplatch and downlatch cylinders; *gear* sequence valves are positioned by door movement. When the control handle is moved to DOWN, the door sequence valve ports pressure to lower the doors. Door movement actuates the MLG sequence valve to unlatch the gear uplatch and to lower the gear. The gear downlatch mechanically positions the door sequence valve to raise the doors again.

Moving the landing gear control handle to UP, essentially reverses the process to retract the gears by porting fluid through gear-up lines.

Emergency extension is by a combination of pneumatic and mechanical means. MLG accumulator air

pressure opens the doors. The emergency gear-down handle, in its first third of travel, positions the emergency spool in the selector valve to block hydraulic pressure and vent the lines to return, and at the same time opens an air valve to admit air to shuttle valves on the door actuating cylinders. The shuttle valves prevent air backing up in the hydraulic lines; air pressure drives the cylinder piston to unlatch and open the doors, and holds them open by air pressure. The second third of travel of the emergency lever mechanically unlocks the door latches, in the event of failure of the pneumatic system to operate, and the last third of travel mechanically unlocks the main and nose gear uplatches, allowing the gears to "free fall."

In "880" aircraft (but not in the "600") a landing gear speedbrake handle is provided, to lower main gears only for deceleration. Hydraulic operation is the same as that controlled by the landing gear handle, except that the speedbrake handle operates cable controls for only the MLG selector valve and not for the nose gear. The speedbrake handle will not lower the main gear unless the landing gear handle is in NEUTRAL position.

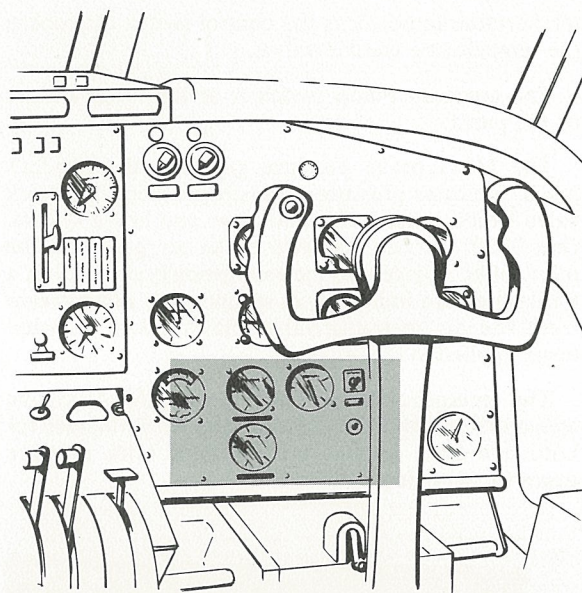
Brakes are normally operated by pilot toe pressure on the rudder pedals. The movement is transmitted to metering valves, one for the nose gear and one for each main gear. The metered flow is to a lockout that isolates the pressure line from the brake actuators. The actuators themselves are small interconnected cylinders at each wheel that compress the disc stack.

The brakes are controlled by the Hytrol antiskid system, by means of detectors, electrical control circuitry and valves, and a pressure modulating accumulator. A flywheel inertia mechanism at each wheel senses incipient wheel deceleration and cuts off hydraulic pressure to that wheel brake before the wheel locks, reapplying pressure when the wheel accelerates. The accumulator, which is ahead of the metering valve, has a restricted inlet that progressively lowers brake pressure when brake reapplications come in rapid succession. This provides only the required safe brake pressure for the rolling speed at the moment of application, and results in smooth, even deceleration.

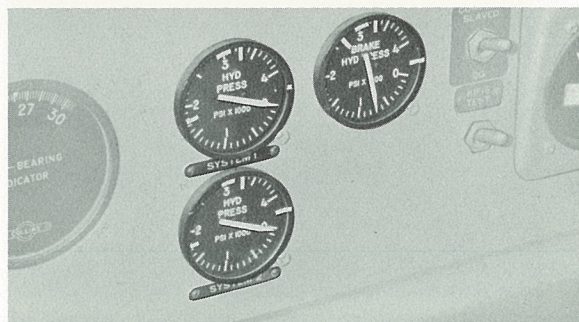
A 400-cubic-inch air flask, charged to 2200 psi, is carried adjacent to the nose wheel well for emergency operation of the main wheel brakes. Pilot control is by a spring-loaded lever on the engine instrument panel. The knob operates an air metering valve. Air pressure is admitted to the brake actuators via a shuttle valve.

Emergency operation overrides both the hydraulic and Hytrol systems. The air flask supplies approximately nine full brake applications at the main gears — more, if the pressure is not fully vented between applications.

A parking brake handle on the instrument panel is essentially a detent on the brake actuating linkage, and functions only to hold the brake metering valves open. The main landing gear accumulators will hold



Gages on left, on copilot's instrument panel, indicate No. 1 and No. 2 system pressures. Third gage shows hydraulic brake pressure available.



brake pressure for several hours after engine shut-down.

INSTRUMENTATION

Main pressure gages for the two hydraulic systems, and the MLG brake pressure gage, are on the lower portion of the copilot's instrument panel. Most of the remainder of the instrumentation and the controls are on a subpanel at the upper left corner of the flight engineer's instrument panel.

At the top of this subpanel are warning lights for low pressure in each pump pressure line, with the firewall shutoff valve switches just below. The firewall valves would also be closed if the fire control handles, above the engine instrument panel, were to be pulled. There is one supply line low-pressure warning light for each system.

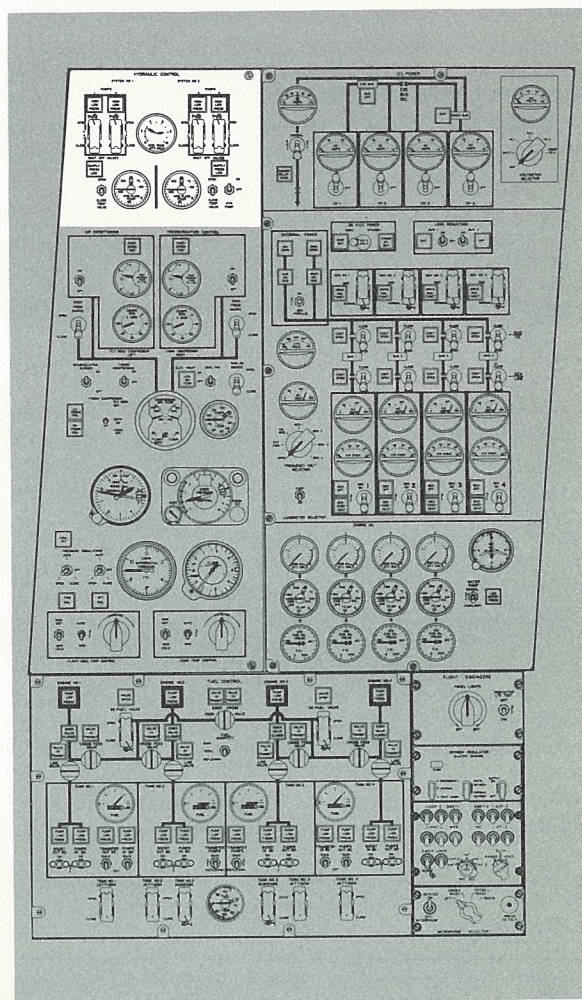
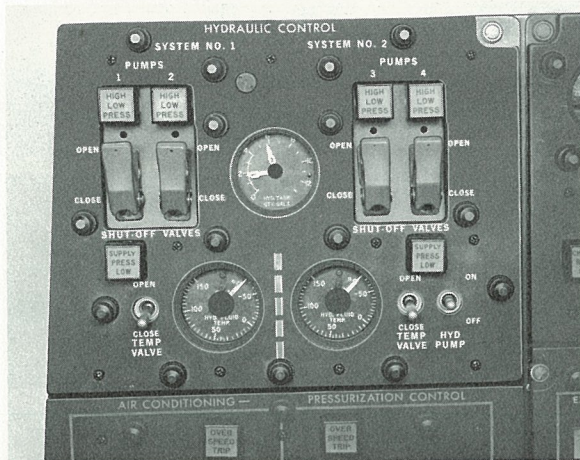
A dual-indicating fluid quantity indicator centered in this panel is operated by transmitters in the reservoirs. There is a temperature indicator for each system; transmitters are in the low-pressure pump supply lines in the hydraulic compartment. Adjacent to each

temperature indicator is the control switch that opens the temperature control valves.

The auxiliary pump switch is at the lower corner of the panel.

The MLG brake pressure gage, on the copilot's panel, indicates pressure downstream from the check valve which isolates the main gear and brake system. One "880" version has two brake air gages on the pilot's side. Adjacent to the emergency brake knob is a bottle pressure indicator. A second gage downstream from the air metering valve shows actual pressure being applied to the brakes.

The emergency brake flask, the two MLG system accumulators, and the pressure line accumulators for both hydraulic systems are equipped with pressure gages for servicing.



Subpanel (left) at upper corner of flight engineer's panel (right) contains fluid quantity and temperature indicators for each system, and firewall cutoff, auxiliary pump, and temperature control switches.

HYDRAULIC COMPONENTS FOR LONG-RANGE "880/600"

The description of the hydraulic systems thus far is applicable to all versions of the Convair 880 and 600 aircraft, except as noted. Differences exist in some areas because of the variance in controls, wings, and fuel systems.

The standard medium-range "880" has four fuel jettison pumps, one in each tank, mounted on the wing rear spar. Two scavenge pumps are provided for emptying inboard tanks. Jettison pumps are operated by the No. 1 system—scavenge pumps by the No. 2 system.

The long-range "880" and the "600" have center section fuel cells requiring, in addition, two combination boost and jettison pumps, one pump for each hydraulic system. The No. 1 system powers both wing scavenge pumps and the outboard left-hand jettison

pump; the No. 2 system powers the other three jettison pumps. This division of pump power sources is to insure that emergency jettisoning of fuel by one hydraulic system, in the event of failure of the other system, will not cause airplane CG to move too far forward.

Both of these larger gross weight aircraft have leading edge slats, operated by both No. 1 and No. 2 systems. Operation is similar to that of the flaps, a central gearbox rotating torque tubes that actuate screwjacks to extend the slats. The selector valve is controlled by the same cables that operate flap selector valves.

In the "600" airplane, the No. 1 system provides power operation of the rudder in certain low-speed situations, when the flight tab does not furnish sufficient surface deflection. At approximately 15° or more deflection of the tab, a hydraulic actuator moves the rudder directly.

Big Job for Teflon*

*TFE resists most chemicals, needs no lubrication,
resists temperatures to 600°F*

Teflon is, in many respects, the most remarkable of the plastics. It is opaque milky white in color, is flexible, and has a peculiar soapy feel. It is one of the smoothest substances known. It retains most of its qualities at temperatures up to 500°F and down to -450°F.

Coefficient of friction between Teflon and polished steel is less than that between fully lubricated metal surfaces. Starting friction is the least of any known substance. This smoothness, combined with heat resistance, has earned Teflon some dozens of uses in Convair jet transports.

For example, the eight engine control cables that are routed through each wing pass through Teflon fairlead grommets. The slightest movement of the flight compartment controls is transmitted to the pylon torque boxes through these low-friction grommets.

Where wing flexure or thermal expansion requires that a tube be allowed to move through a fitting, Teflon-lined clips or fairleads permit a tight-fitting clamp that allows movement with slight resistance. Teflon lining is used, where temperature permits, to hold friction to a minimum.

Telescoping anti-ice ducts for the Convair 600 slats have Teflon seals.

In two applications in "880" and "600" aircraft, Teflon is used for bearings. Ends of the aileron trim tab actuating rods utilize a thin woven Teflon-impregnated bushing between metal surfaces for a lubricant-free bearing that must operate at high temperatures under heavy loads.

In the engine compressor, the variable vanes rotate in Teflon bushings. Other small bushings and seals appear in fuel and oil components. Engine pod firewall air gap seals consist of Teflon-coated asbestos over Inconel mesh. Teflon coating is used as a binder in lieu of synthetic rubber because of its high resistance to Skydrol, engine oil, and fuel.

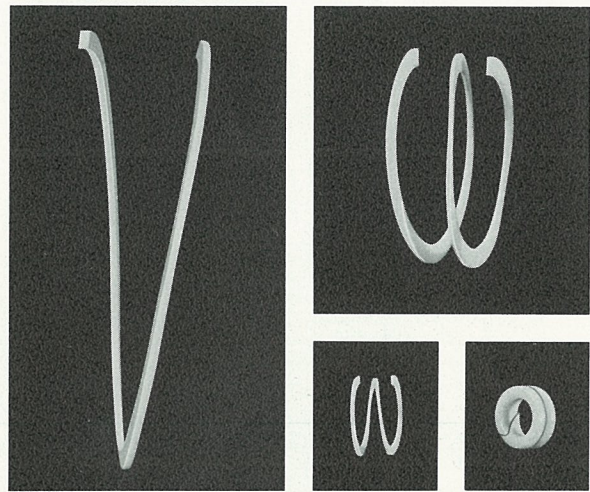
Chemical inertness of tetrafluoroethylene, because of a well-recognized paradox of chemistry, is associated with the fact that the molecule is largely made up of fluorine, one of the most active elements in its free state, and hence one of the most corrosive. The basic formula of Teflon, in a chemist's diagram, is a chain of carbon atoms, each with two fluorine atoms attached. Fluorine's affinity for the carbon is so strong that only fluorine itself, at high temperatures, and molten alkali metals will attack the compound.

(*) Dupont trade name for tetrafluoroethylene.

Teflon is thus immune to deterioration from contact with petroleum products, acids, caustics, and all solvents. Because it is impervious to Skydrol hydraulic fluid, it is used extensively throughout Convair jet airliners.

Teflon's high dielectric strength finds application in coaxial cables and in some "blackbox" wiring.

All hydraulic flexible hoses, and all the Aeroquip fluid hoses in the pod-pylon assembly are Teflon-lined.



Teflon backup ring, left, is from landing gear actuator. Other backup rings shown are double thickness. At lower right is a typical fairlead.

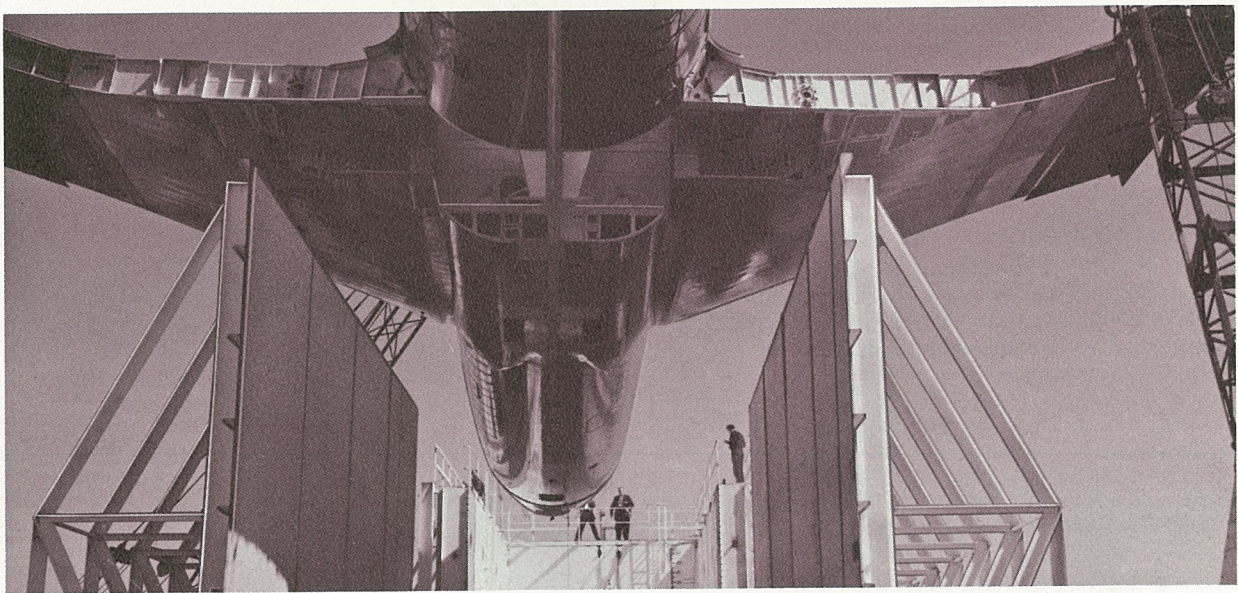
Teflon is used for backup rings throughout the hydraulic systems. Not soft enough to make a good "O" ring for most purposes, it is perfectly adapted to backing up the seal formed by a butyl "O" ring. Typically, the backup rings are split and beveled at the ends for overlap. They can be quickly fitted, and trimmed to exact dimension by a sharp knife.

Teflon parts may be drilled or machined with sharp lathe tools or milling cutters. High temperature limit of the material, for practical purposes, is given as 500°F, although a little change occurs up to 620°F, where it softens. It does not liquify. At 750°F, Teflon molecules begin to break down.

The gaseous products of this disintegration are harmful. For this reason, ventilating hoods, blowers, and thorough area ventilation are required in areas where Teflon is being machined or processed.

11 44

Shown going into a big hydrostatic test tank is a specially built test fuselage of the Convair 880 jet airliner. The fuselage is equipped with stub wings from which it hangs in the tank. The test is designed to ensure trouble-free Convair 880 service for many years ahead.



During the tests, the fuselage is filled with water and surrounded by water in the tank. Water inside the fuselage is pumped up to 8.6 psi (normal operating pressure differential of the Convair 880 is 8.2 psi). At the same time, loads are applied by hydraulic rams attached to straps riveted to the fuselage at the wing stubs.

Each test cycle, which is a combination of pressurization loading and simultaneous application of wing and fuselage loads, represents a takeoff, flight, and landing. In this way, 20 years of service can be compressed into seven months of testing.

Underwater television and skin divers are utilized for frequent inspections during the test period.

CONVAIR SAN DIEGO

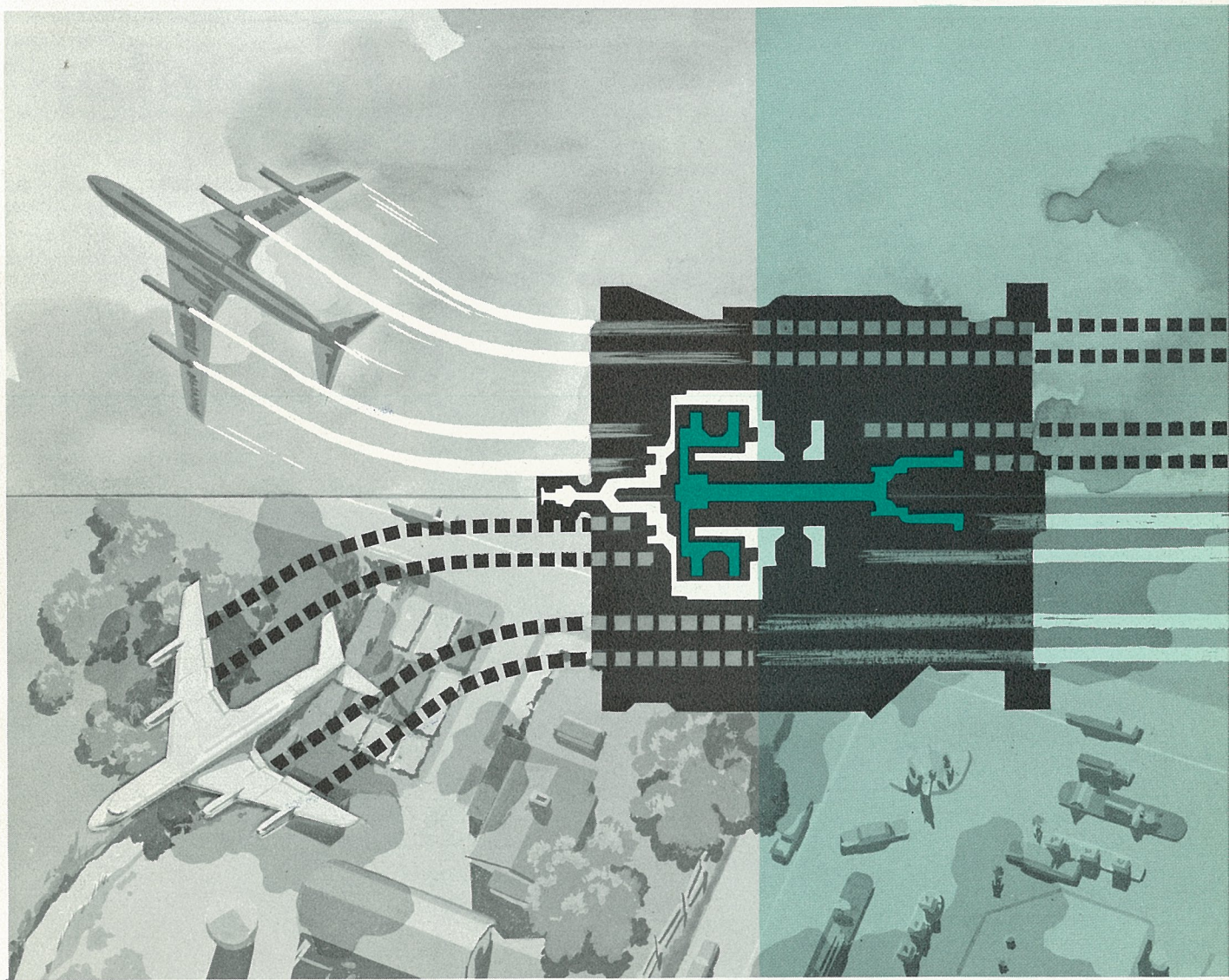
CONVAIR DIVISION

GENERAL DYNAMICS CORPORATION

VOLUME XI NUMBER 3 JULY 1959



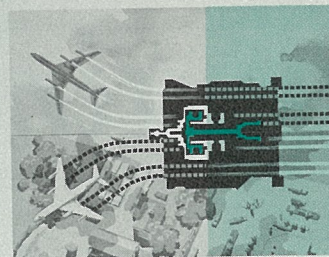
Convair **Traveler**



In this Issue: The Constant Speed Drive

VOLUME XI NUMBER 3 JULY 1959

Convair *Traveler*



In this Issue: The Constant Speed Drive

OUR COVER

At maximum takeoff setting or with engine idling, the constant speed drive taps off power at whatever rpm the engine provides and transmits it at a steady 6000 rpm to the airplane generators. The concept is Artist Norm Harrington's.

Convair *Traveler*

VOLUME XI NUMBER 3 JULY 1959

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"880" JET AIRLINER ENGINEERING TEST PROGRAM

N. V. Davidson

A digest of operation and service published monthly by the Service Publications Sections of Convair Customer Service Department in the interest of Convair operators. Communications should be addressed to the Manager of Customer Service Department, Convair, San Diego 12, California. Information is to be considered accurate and authoritative as far as Convair approval is concerned. FAA approval is not to be implied unless specifically noted. Recipients of this information are cautioned not to use it for incorporation on aircraft without specific approval of their cognizant organization.

The Constant Speed Drive

A major advance in aircraft electric power systems made possible by a breakthrough in mechanics

Constant speed drives of the type that drive the a-c generators in the Convair 880 and 600 aircraft have a special interest for those with a mechanical inclination. They are the first effective solution of an engineering problem as old as machinery. Many partial solutions have been worked out, but no real answer has been found until recently.

The problem is to make a power transmission unit whose input shaft may revolve at variable speed, but whose output shaft speed will remain constant, regardless of load. When a-c generators are to be operated in parallel, as they are in the Convair jet airliners, the speed must be constant within narrow limits, no matter where the pilot may set the engine power lever or what sudden current supply he may demand when he operates a switch.

To make clear what a constant speed drive must be designed to do, imagine one installed in an automobile. It would replace both clutch and transmission; the engine would turn the input shaft, the output shaft would turn the wheels. The CSD would be set for 10 mph and engine idle speed adjustment would be set fast enough to supply a surplus of power.

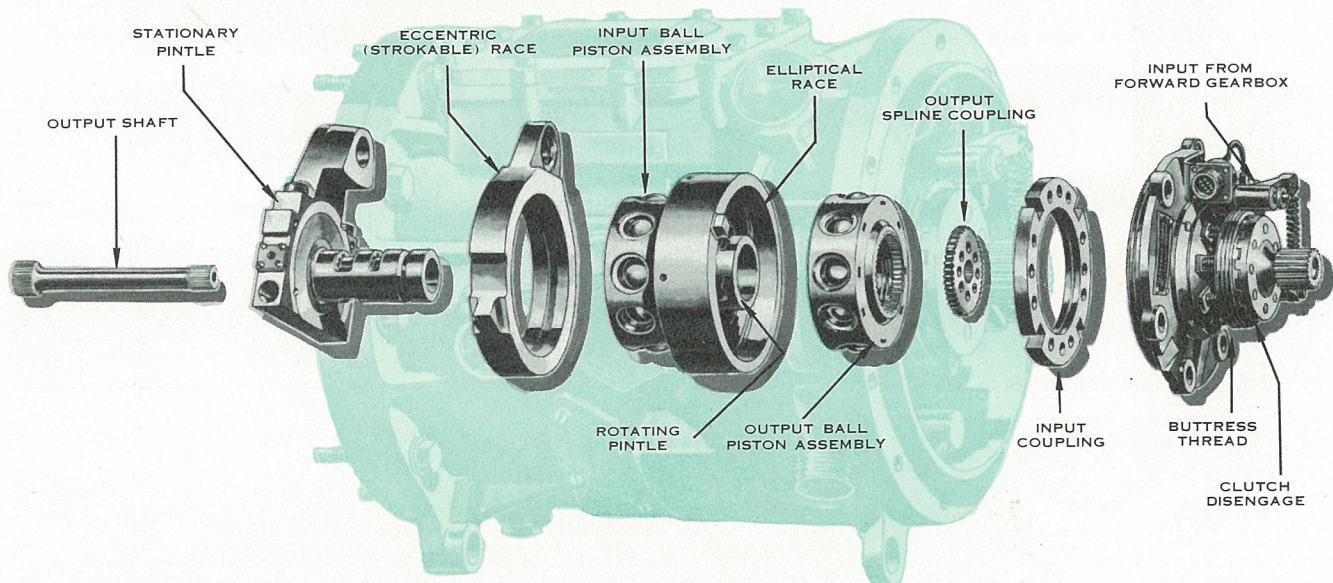
When the driver starts the engine, the car will move off smoothly until it reaches 10 mph. Then, uphill and down, on the highway or in a mudhole, the wheels will turn at 10 mph. Lift the car off the ground and the wheels will keep turning steadily; drop it suddenly, and the tires will "burn rubber"—losing $\frac{1}{2}$ mph for an instant, but picking up again to 10 mph wheel speed before the car has had time to move from the spot.

Meanwhile, the driver sits and "guns" the engine to a roar or lets it "lug down" almost to stalling. Whatever he does, the engine will drive him up the steepest grade, on glare ice or through deep sand, at never less than 9.9 or more than 10.1 mph.

Such a transmission obviously represents an advance far beyond the contemporary automobile automatic transmission, which is regarded by the average motorist, with some justice, as already a pretty complicated gadget. Adding more complexity to the automotive type of transmission, with even more planetary gears and clutch transitions, could never meet the a-c generator requirements for high-speed jet aircraft. What was required was an engineering breakthrough.

The General Electric CSD unit in the 880 and 600, with far fewer parts and much less weight, holds the Convair transport a-c current at 400 cps $\pm 1\%$ (6000 generator rpm $\pm 1\%$) with engine rpm from idle to takeoff (approximately 4500 to 7680 rpm) under electrical loads varying from 0 to 40,000 volt-amperes—equivalent to a 64-horsepower load.

The CSD is a hydraulic unit, mounted at the forward face of the forward engine gearbox, with the generator attached at the aft face. The basic mechanism is built around the ball piston design that is utilized in many high-speed high-pressure hydraulic pumps. Cylinders are radially machined into a cylinder block rotor that revolves on a pintle; the pistons are free-moving precision steel balls. The balls are moved by revolution of the rotor within an eccentric, or elliptical, race. Ports at the inner ends of the cylin-



Exploded view of constant speed drive transmission unit

ders, and on the outer surface of the pintle, admit or vent hydraulic fluid to or from the cylinders, depending on the angular positions of the rotor with reference to the pintle (see drawing).

Forcing fluid through such a pump in reverse flow causes the pump to function as a motor. The pressure of the fluid forces the ball against the eccentric surface of the race, with a resultant torque moment that moves the rotor within the race.

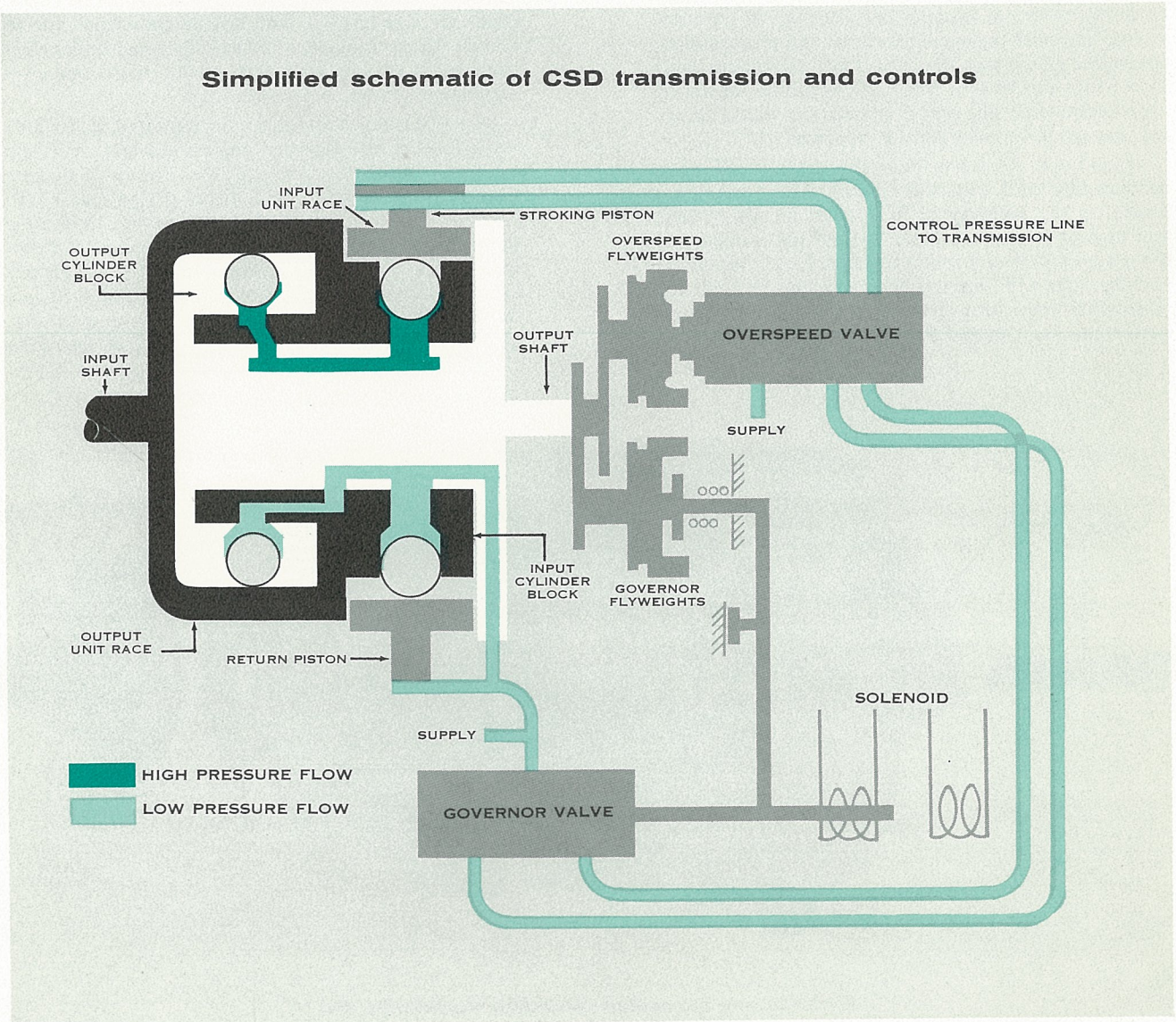
There are two such ball piston assemblies in the General Electric CSD unit. One rotor, containing seven 1-inch cylinders, is driven by the input shaft; the other has nine $\frac{7}{8}$ -inch cylinders and is splined to the output shaft. The input race is circular and is positioned eccentrically, so that the assembly is a variable-displacement pump. The output assembly race is elliptical, so that the assembly makes up a fixed-delivery pump. The fluid is MIL-L-7808C lubricating oil,

identical with that used for engine lubrication, and is stored in a separate compartment of the engine oil tank.

To understand just how it functions, a glance at the exploded view of the components on page 3 will show some essential features. An important item to bear in mind is that the input rotor, the output (elliptical) race, and the output rotor pintle may be considered one integral part; output race and pintle rotate along with the input cylinder block rotor at input rpm. Input race and pintle are non-rotating. The input race is mounted on a pivot and may be moved to either side of center; flow is therefore reversible, depending on which side of center the eccentric race is positioned.

Position of the input ("strokable") race is set by cylindrical pistons mounted so as to bear on opposite sides of the race. One of these pistons functions only to maintain a constant high pressure; the other, termed

Simplified schematic of CSD transmission and controls



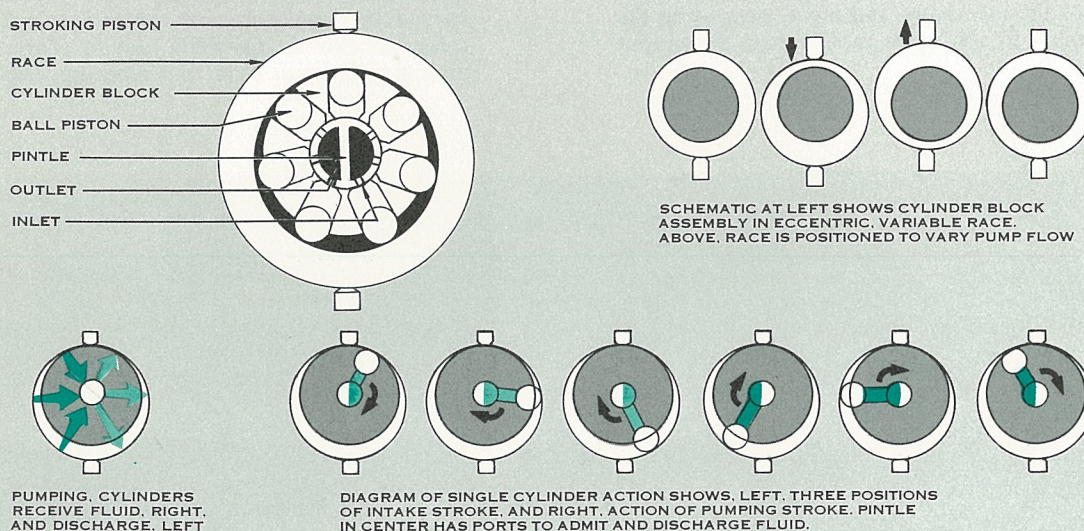
the "stroking" piston, is positioned by hydraulic fluid (CSD system oil) exerting pressure on either side of the piston head. Travel of the stroking piston is governed by two controls. One is a flyweight governor, responding to output shaft speed, and the other is an electrical solenoid actuated by load-sensing elements and so able to compensate for electrical load requirements.

With these principal elements of the unit in mind, it is possible to trace the mechanics of the operation. The two ball piston cylinder block rotors are linked hydraulically through the output (rotating) pintle that turns with the input rotor. The usual explanation is that one of the two hydraulic units functions as a pump and the other as a motor; which one is pumping depends on which is turning slower. This is true in terms of fluid flow, but may be misleading, since the input assembly always drives the output, regardless of di-

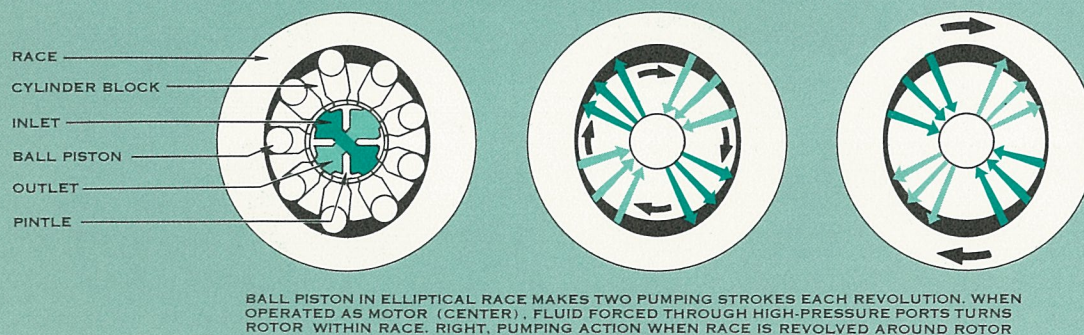
rection of fluid flow. Pumping action of the input assembly occurs when power is applied to the input rotor; pumping action of the output assembly occurs when the elliptical race is driven faster than its rotor.

While it might seem logical to begin with the engine at zero rpm, explanation may be simpler by beginning with zero fluid flow condition. This is the status when engine and generator are both turning at 6000 rpm, a transient condition that normally exists only during acceleration and deceleration. At that instant, the input race is centered, the input ball pistons are not moving in their cylinders, and there is no fluid flow to or from the output cylinders. Half the output ball pistons, being hydraulically connected to half the input cylinders, are therefore hydraulically locked at varying depths in the cylinders. The elliptical race, turning at input shaft speed, will turn the output rotor, and hence the output shaft, at the same speed as that of the input shaft.

Variable-displacement ball piston pump with eccentric race



Fixed-displacement ball piston pump with elliptical race



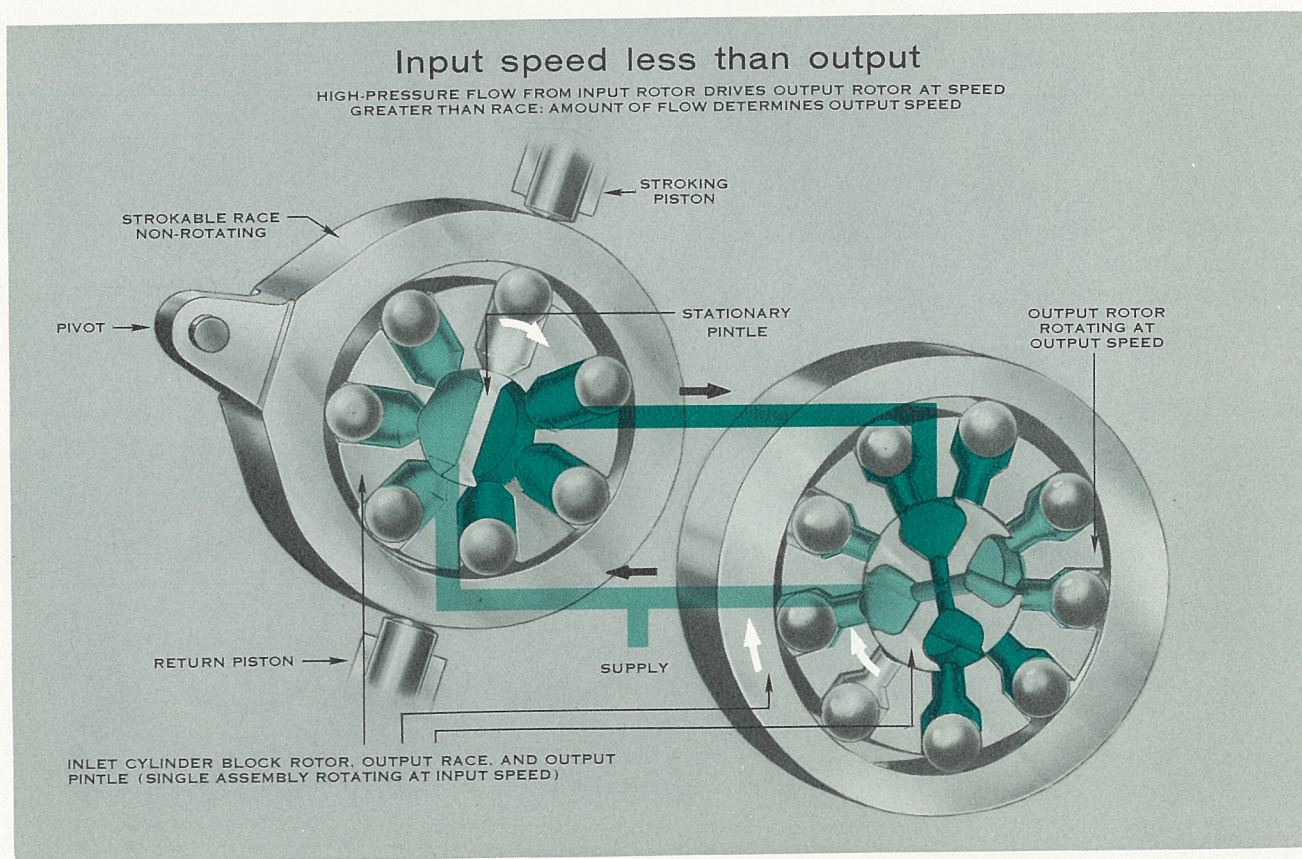
Now, assume that engine rpm drops. As soon as the flyweight governor senses a speed decrease below 6000 rpm in the output shaft, it will port fluid to the stroking piston and the strokable (input) race will be moved toward the position indicated in the drawing on page 6. The ball pistons will pump fluid into the output cylinders; the pressure on the output ball pistons will force the rotor to move faster than the race, and output shaft speed will increase until it reaches 6000 rpm. The governor will hold this speed by regulating fluid flow to position the strokable race.

Assume that engine speed increases above 6000 rpm, the normal operating condition during flight. Then the governor will move the input race toward the position indicated in the drawing on page 7. Fluid will begin to flow from output to input cylinders. Since the load of the generator is a constant drag on the output shaft, the elliptical race will begin to slip past the rotor, by this action moving the output ball pistons so as to the pump fluid back toward the input cylinders. The differential in output and input speeds will be limited by the rate at which the input assembly pumps fluid—or, rather, permits fluid to pass—back into the supply, and this rate will be governed by position of the input race. As engine speed increases, the governor will displace the race more and more, permitting the input assembly to slip more rapidly past the output rotor.

It is evident that the governor must furnish sensitive speed control. In principle, it is a standard flyweight type with a reference spring, operating a servo valve that ports fluid to one or the other side of the stroking piston. The governor is driven by an accessory drive set of gears mounted within the CSD case at the output end.

A-C generators operating in parallel not only must maintain a synchronous frequency—i.e., identical rotor speeds—but also must share equally in bearing the electrical load. To provide the fine control required for this load division, an electrical control is superimposed on the governor control, by means of a load-biasing solenoid that acts directly on the servo valve. The solenoid is operated by the load controller, a sensitive "black box" unit that senses real load on the generator. Load controllers for all generators are electrically interconnected; when load on one generator increases or decreases relative to the loads on the others, the load controller directs an impulse to the solenoid to provide more or less CSD output power.

For such a high-speed heavy-duty transmission, safeguards are necessary. The CSD is a linkage between a power source that, for this purpose, may be considered unlimited, and a generator whose drag may exceed 100 horsepower momentarily. There are four safeguards within the CSD unit to protect the CSD and/or the generator: an underspeed-overspeed assem-



bly, an overrunning clutch, a disengage clutch, and a shear section.

Along with the control governor is a separate independent overspeed governor, operated by a gear on the output shaft. A second flyball governor, in the same housing, actuates a switch that cuts the generator off the line if speed falls below limits. The overspeed governor, if output speed should exceed approximately 7200 rpm, actuates a separate overspeed servo valve that applies an overriding hydraulic pressure to the stroking piston, forcing the drive to an underspeed condition. The underspeed switch then cuts the generator off the line. The servo valve will reset automatically when CSD speed falls to almost zero, as on engine shutdown.

The overrunning clutch is in the output shaft assembly. Should the generator attempt to motor the CSD, the generator will be automatically disengaged.

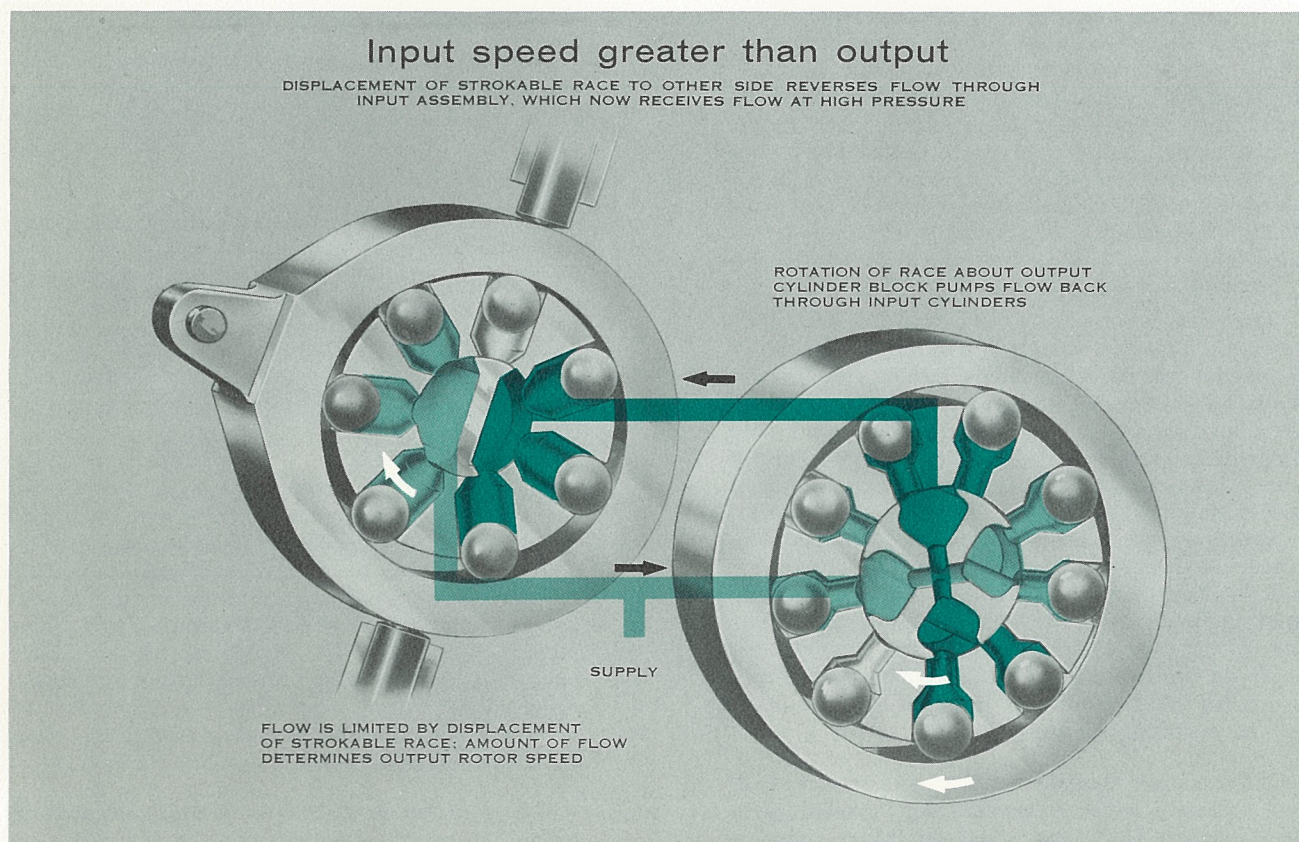
On the input end is a quick-disconnect assembly that can be operated from the flight compartment. The assembly consists of a mesh clutch, one plate of which moves on a splined shaft. Normally, the plate is meshed with the drive assembly. On its circumference is a coarse buttress thread. A sector arm, operated by a solenoid controlled by a switch on the flight engineer's panel, can be dropped into the buttress thread, and the sliding clutch plate will be driven back to disengage from the drive plate. This discon-

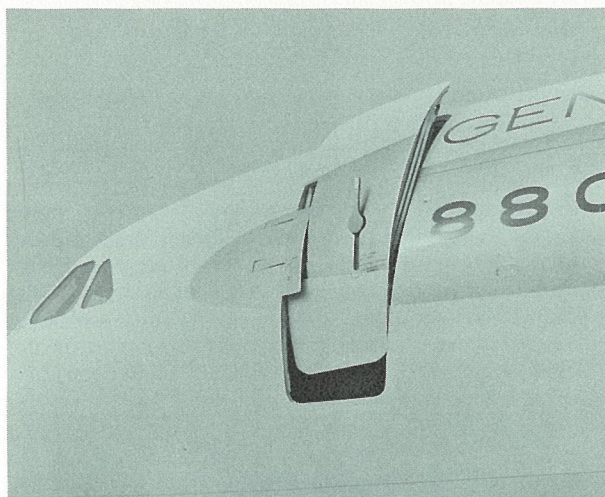
nect cannot be reset until the engine is stopped and the sector arm pulled out manually to allow the plates to mesh.

The shear section is part of the CSD input shaft. It fails under excessive torque, as a final protection against major malfunction in the drive or generator.

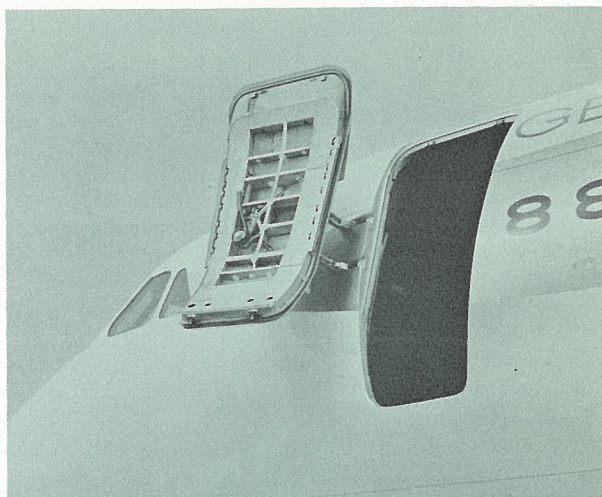
A load limiting switch, mounted on the engine tachometer outside the CSD unit, keeps the generator off the line until the engine reaches idle speed and, after it drops below idle on shutdown, relieves the CSD from low-speed loading. A thermal switch in the CSD case illuminates a red warning light on the flight engineer's panel, should CSD oil temperature become excessive.

The CSD oil system requires both supply and scavenge pumps. They are in one housing and are driven by the CSD accessory drive assembly. Both are positive-displacement type. The supply pump maintains 140 to 150 psi in the CSD; the scavenge pump maintains 110 to 130 psi in the return lines and the reservoir. A 10-micron filter in the supply lines removes dirt or metal dust before the oil is delivered to the ball pistons. The return supply to the reservoir passes through oil-to-air and oil-to-fuel coolers. The air cooler uses ram air, the flow of which is controlled by a motor-driven valve. The valve opens and closes automatically to maintain oil temperatures at approximately 240° to 275° F.





Door nearly closed on parallel hinge. When fully closed, door, hinge, and handle are flush.



Passenger door in fully raised, open position. Trim is removed to show operating mechanism.

Convair 880/600 Cabin Door Sealer

... Fail-safe cabin pressurization in the Convair 880/600 jet airliners is assured with development of two unique features — the plug-type door and the Convair Flex-Support Seal ...

Because the "880" is designed to fly at higher altitudes and employs higher cabin pressurization, entirely new passenger entry and service doors were designed. These doors use a double-hinge principle. The hinges are completely flush when the doors are closed so that the door and its hinges contour smoothly into the fuselage shape. On one hinge line of the double hinge, the door is arranged so that it slides upward. The main passenger door, for instance, has a nine-inch movement in an upward direction as the first action in releasing the door from its fully locked position. When open, the door is parallel with the fuselage.

The doors are contoured to fit the fuselage curvature, but are wedge-shaped in plan form. This wedge shape, plus an upward sliding motion, permits the doors to be wedged, or more truly "plugged," into the door frame. The door and the door frame have long tracks along their sides which engage when the door is lowered, and disengage when the door is raised. Additionally, at the top of the door, two T-shaped members engage T-shaped slots on the upper door frame; at the bottom, two pins on the door engage holes in the door sill. The side tracks, the T-shaped engaging members at the top, and the pins at the bottom of the door serve to transmit the pressurization loads on the door to the fuselage. This door design precludes the possibility of the door opening under any normal flight condition.

These unique fuselage entrance and service doors will be sealed under pressurized flight conditions by the Convair Flex-Support, self energized, bulb-dia-

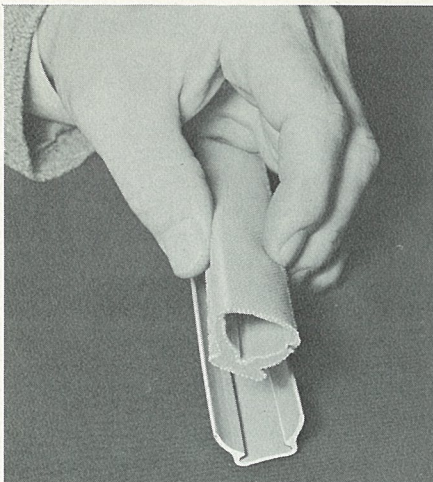
phragm seal. The seal is a new concept in fail-safe high-pressure sealing and is in step with other advance design features embodied in the Convair 880 and 600.

The seal is constructed of high-strength silicone rubber, reinforced with two-way stretch dacron fabric; an inner and outer pressure wall precludes loss of pressurization in the event of unforeseen damage to the outer wall.

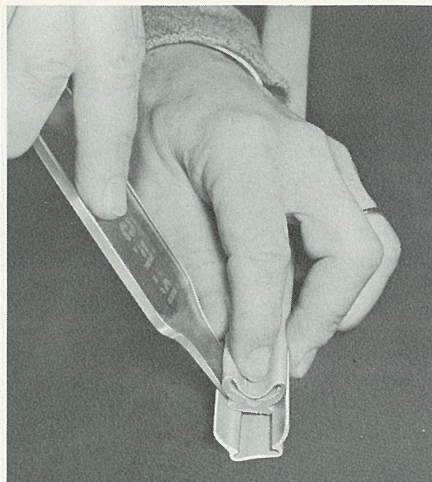
The Flex-Support, a fail-safe feature, is integrally molded within the seal to eliminate the possibility of seal collapse. This flexible spring wire supports the sidewalls of the seal against lateral pressure loads, when pressurized, to assure positive alignment between the seal diaphragming crown and the fuselage striker. The fuselage striker is placed opposite the center line of the seal so that it will depress the seal crown when the door slides closed.

The seal is automatically self-energized by the difference in pressure between the cabin and atmosphere through a series of small vent holes between the convolutions of the flex support on the cabin side of the seal. This permits cabin air pressure to enter the seal and to diaphragm the stretchable crown firmly against the fuselage striker. The higher the pressure differential, the tighter the seal presses against the striker. Then, when pressure differential is equalized, the seal relaxes, and wear from the sliding and wiping action of the door is minimized.

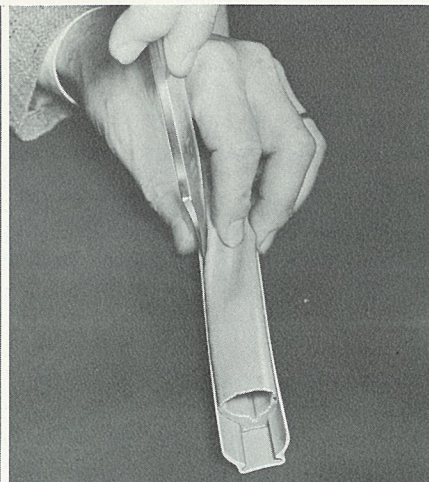
Design of the door structure is such that positioning of the seal retainer in various convolutions was



Shown is bulb-diaphragm door seal and extruded door seal retainer.



Bulb-diaphragm door seal is started in retainer with blunt plastic tool.



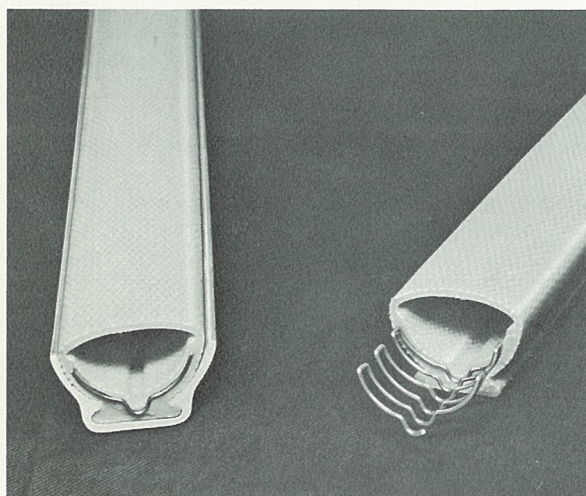
Shoulders of the seal are worked in progressively along the retainer.

necessary to align the seal crown with the fuselage striker so as to effect positive sealing when the door is closed; yet, at the same time it must clear the fuselage striker and track structure as the door moves upward nine inches before opening. These conditions are easily accommodated by the new seal because although the "Flex Support" gives the seal a stiffened cross-section and proof against lateral pressure loads, it remains extremely flexible in the longitudinal direction to facilitate installation on highly contoured surfaces.

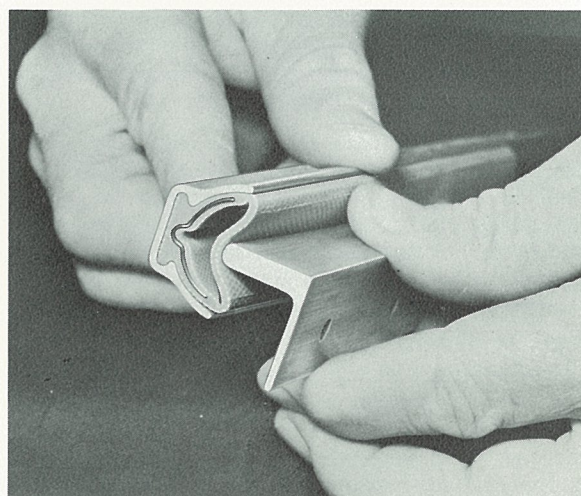
More than 6000 wiping action cycles, conducted concurrently with pressure cycling tests to 8.6 psi, have proved that the new Convair flex-support, self-energized, bulb-diaphragm door seals will meet all operational requirements. The fail-safe qualities of

the seal were checked by deliberately cutting the seal while it was pressurized to 8.6 psi. Little pressure drop was noted. In an attempt to "fail" the seal, the cut was increased to a triangular hole. The seal continued to hold tightly against the striker at all points because of the steel flex-support, with no indication of seal collapse, blow-by, or explosive decompression. There was some bleed-off at the point of puncture. To further test the seal, it was placed on a high-pressure test stand and subjected to the full test gage limit of 35 psi without failing.

For comparative purposes, the identical tests were performed on a variety of other seals. The eventual failure of the seals provided conclusive proof of the superiority of the "Flex-Support," self-energized, bulb-diaphragm seal.



Left: Flex-support seal in section of extrusion. Right: Door seal with flex-support wire exposed.



Contact between flex-support seal and striker. Cabin pressure "wraps" seal around striker.

"880" Engineering Test Program

To insure performance, safety, and structural integrity of the Convair 880 jet airliner, an exhaustive test program was initiated months ago and is now well on its way to completion. Thousands of hours of wind tunnel testing at the Convair low-speed wind tunnel and at the Southern California Cooperative Wind Tunnel, preceded Engineering Structural and Flight Test Programs.

The 14-month flight test program now well along, utilizes three Convair 880's, two heavily instrumented and one with a completed interior for air conditioning, acoustics tests and final systems tests.

Concurrently, many tests are being carried out on structural subassembly components to verify design configurations. The fruits of this basic groundwork are showing up in the actual flight testing which has been progressing smoothly toward completion.

The Engineering Test Program in the early design stages utilized relatively small panels of fuselage and wing skin for strength and fatigue research. Successively larger sections of fuselage and wing were constructed in the experimental factory for proving out systems, acoustics properties, air conditioning, and pressurization.

As production progressed, the test program kept pace by including actual factory items to acquire data for comparison with earlier research.

The Engineering Test Program, in addition, utilized a production airplane for a year-long program of proof-load testing. In this program the loads generated by flight are applied under controlled laboratory conditions, engineers pointing out that under flight conditions it is not possible to determine whether limit loads have been achieved.

The production airplane being used in these tests is undergoing severe structural loading conditions. The wing, tail surfaces, fuselage, and landing gear are subjected to loads by means of hydraulic rams connected to the airplane by whiffletrees, contrivances similar to the pivoted bars between horse and wagon.

In one of these tests, fin torsion is combined with fuselage bending, a condition in which the maximum anticipated rudder loading is combined with a simultaneous gust load. This is a cumulative load condition which the airplane *could* encounter; however, if the airplane is being flown in accordance with flight instructions, the possibility of such loads actually being encountered is extremely remote.

During this exhaustive test, the amount of skin wrinkling temporarily encountered under load, was noted to be less than is ordinarily experienced. When the high loads were released, there was no resultant permanent deformation which could jeopardize structural integrity.

Testing to prove out the service life of the airplane

is also under way at the Structures Test Laboratory. An entire fuselage, including stub wings, is hung in a huge tank, and immersed in water. Water inside the fuselage is pumped up to 8.2 psi which serves to create a 6000-foot simulated altitude in the cabin when the Convair 880 flies at 35,000 feet. The fuselage will undergo testing simulating more than 20 years of airline service.

A unique aspect of the Convair hydrostatic test is that the specimen includes stub wings. Structural relationship between wing and fuselage is tested by means of hydraulic rams attached to the fuselage. The specimen is pulled upward and downward to simulate the forces encountered when the airplane taxis and when it flies. Earlier testing proved out the ruggedness of the structure of the Convair 880; this test is designed to prove its ability to hold up under years of operational work. Thus, the "880" is preproofed to the equivalent of 20 years of service life well before the first production airplane enters regular airline service.

A complete list of the tests being run is too long to enumerate, yet some of the following objectives will indicate the range of testing that is being focused on the complete aircraft.

Hailstones the size of golf balls have been fired against samples of the wing and tail leading edges, to make sure that if any such oversized hailstones should strike these vital areas in flight, structural integrity would not be impaired.

There is a possibility that the high-speed "880" might encounter migrating birds. To test the strength of the windshields, birds were fired at near sonic speed directly into the windshields.

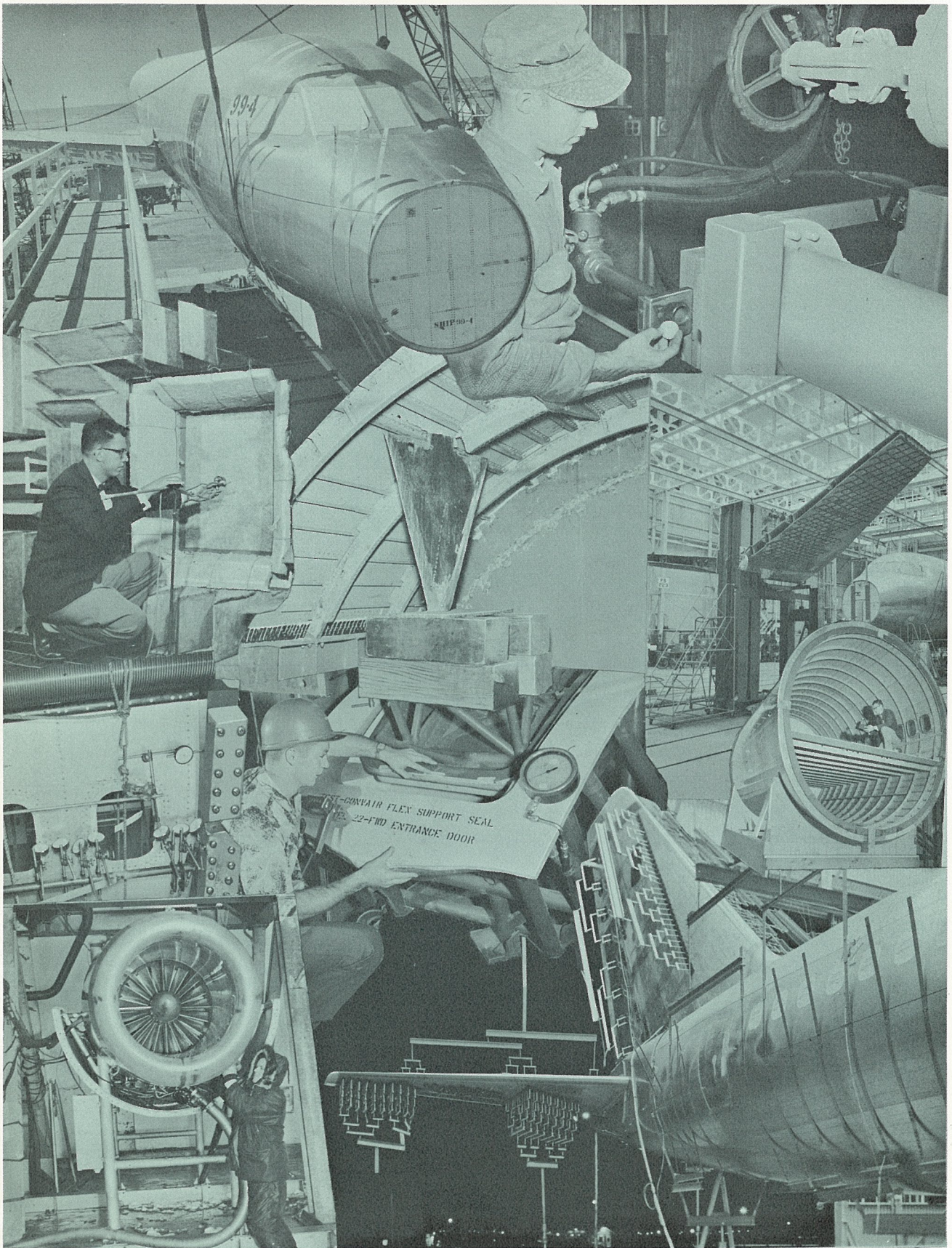
Passenger windows were deliberately damaged and subjected to full cabin pressure differentials, to check their inherent reliability under adverse circumstances.

New type seals in Convair's plug type doors, were tested through thousands of cycles to establish their reliability and to check the life of the seals.

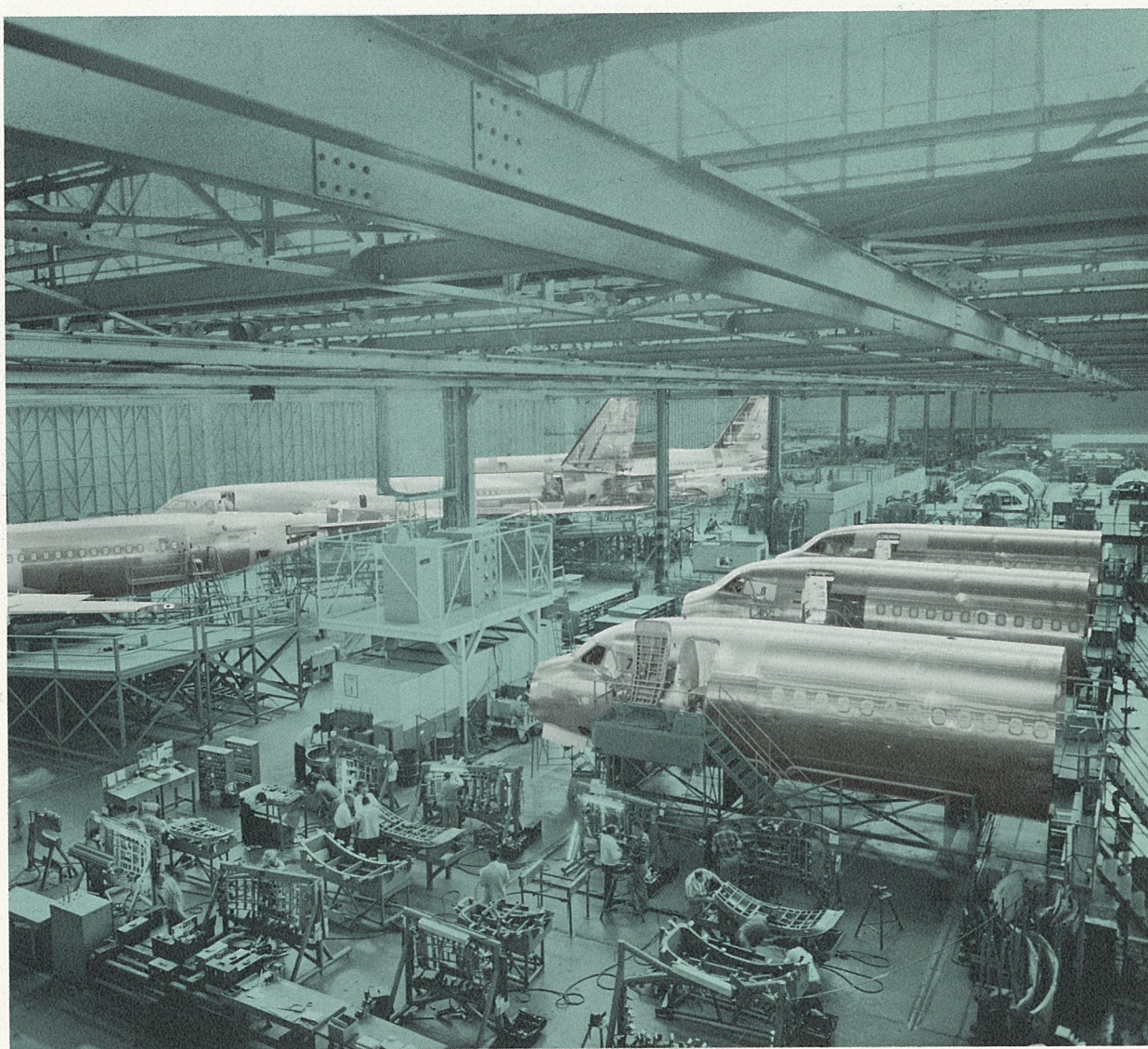
Wing stringers and fuselage skin were cut and a load applied to produce failure of the section at or above the fail-safe load of 53.5 percent of design limit load. If no appreciable growth of the crack developed in 500 or more applications of the test load, the cut was increased and the procedure repeated until the member failed.

Numerous segments of the fuselage were subjected to cyclic cabin pressure fatigue tests with pressures up to 9.3 psi. A 19-inch javelin blade forced through the skin and beltframe while the specimen was pressurized to 9.3 psi showed no crack growth at the ends of the cut and specimen slowly depressurized.

These tests and others, which have not already been discussed, will be covered in further detail in future issues of the Traveler.



This view of one of the two assembly buildings shows some of the 11 Convair 880 jet airliners now on the production line or in major assembly fixtures. In the foreground are forward fuselage sections for airplanes 7, 8, and 9. In the background are airplanes 6, 5, and 4. No. 4 airplane, the third flight test airplane, will be the first one with a finished interior. It is expected to leave the factory late this month.



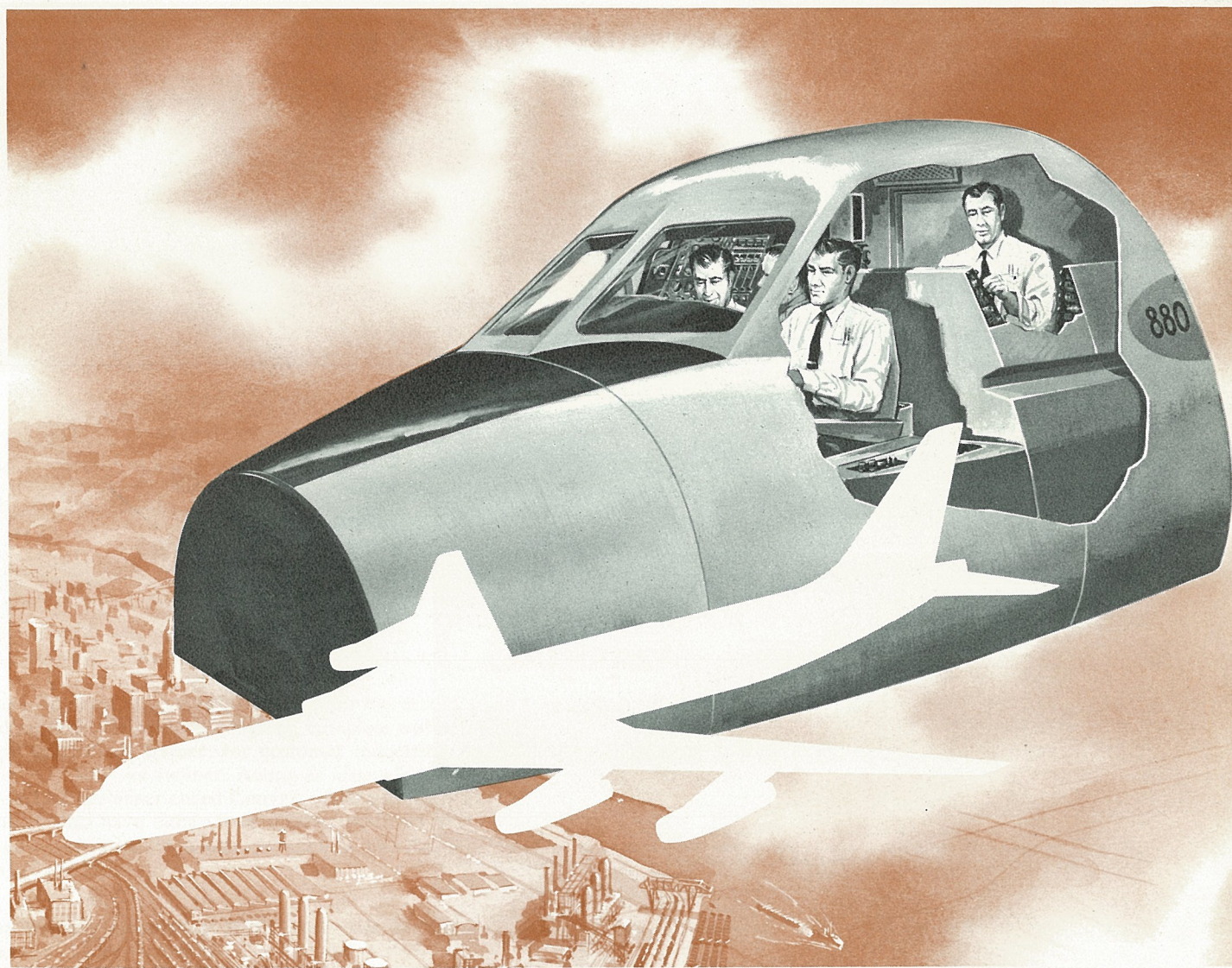
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VOLUME XI NUMBER 4 AUGUST 1959

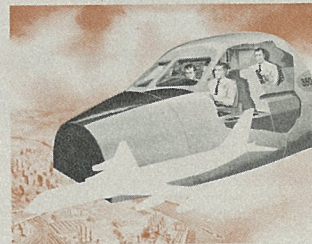
Convair Traveler



In this Issue: "880" Flight Crew Training

VOLUME XI NUMBER 4 AUGUST 1959

Convair *Traveler*



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OUR COVER

Next to actually flying the "880," the best training a flight crew can get is to take a "ride" in Convair's new flight procedures trainer.

Convair *Traveler*

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DESIGN FEATURES OF CJ805-3 ENGINE

R. E. Weymouth
(G-E Engineer)

A digest of operation and service published monthly by the Service Publications Sections of Convair Customer Service Department in the interest of Convair operators. Communications should be addressed to the Manager of Customer Service Department, Convair, San Diego 12, California. Information is to be considered accurate and authoritative as far as Convair approval is concerned. FAA approval is not to be implied unless specifically noted. Recipients of this information are cautioned not to use it for incorporation on aircraft without specific approval of their cognizant organization.

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Accurate 1/32-scale plastic model of transport facilitates study of major systems.

"880" Flight Crew Training

*Program includes use of Flight Procedures Trainer
for simulating flight conditions and related navigational problems*

The "jump to jets," and transition from one type aircraft to another is much easier for pilots, copilots, and flight engineers if they have thorough training, initially. To take full advantage of this fact, Convair has established an extensive training program, complete with a cockpit procedures trainer, for customer indoctrination in the "880" jet airliner. Acting as instructors in the program are experienced Convair pilots and flight engineers who have either been directly involved or worked closely with the design, production, and flight testing of the "880."

The training program is being conducted by the Production Flight Section of Convair and is divided into the two customary phases, ground and flight. The flight training phase of the program is at the option of the operator. While both phases are normally accomplished at Convair's San Diego facility, either or both

can be made available at the customer's base. In this respect, if the customer so desires, Convair will provide the services of pilot and flight engineer instructors to assist the customer in placing the aircraft into operation, setting up their own company "880" training program, and conducting transitional flight training.

Of five weeks duration, the ground training phase is designed to acquaint pilots and flight engineers with the design and operation of "880" systems and components.

The "backbone" of the ground course is the "880" Flight Training Manual. Written and produced by the instructors themselves, this manual contains only the amount and types of information that are essential to the flight crew. Further, it is written in the flight crew's own language.

Listed are the general topics of study included in the ground school:

Power Plant & Related Systems		
Fuel Systems	Airplane General	
Adverse Weather Systems		
Air Conditioning & Pressurization		
Hydraulics	Autopilot	
Aerodynamic & Thermodynamic Aspects		
Flight Operations		
Operating Techniques	Electronics	
Fire Detection & Extinguishing		
Flight Controls	Instruments	Electrical
Performance Curves	Emergency Equipment	

Classroom training will be supplemented with the use of several training aids such as black-and-white and color transparency projections. Especially helpful will be an accurate 1/32-scale model of the "880." This model is constructed of transparent plastic, which facilitates location and study of the major systems and components. For example, a quick understanding of the general layout and operation of the air conditioning and pressurization system is possible by locating the components and following the associated lines and ducting.

Another valuable classroom aid will be a 1/4-scale breakaway mockup of the aircraft flight deck. This aid will be especially helpful when discussing the location



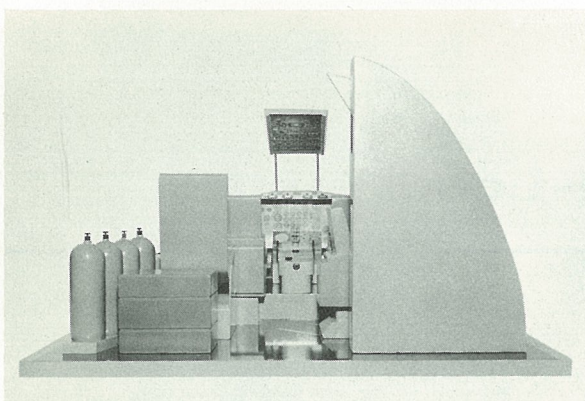
Various flight conditions can be set up by the instructor (left) at his position in the "880" flight procedures trainer, thus creating different types of problems for the flight crew.

and operation of the cockpit controls and instruments. Classroom instruction will be further supplemented by tours of the plant and flight line.

On completion of the ground syllabus, approximately 15 hours of actual flight training in the customer's own airplane begins. Flight instructors will follow a detailed outline in their instruction to insure overall standardization and thoroughness of training among crews. Whenever possible, the flight engineer instructors for the ground course will also be assigned to their respective students for the flight training phase.



Group of operator personnel, representing first "880" customer flight crew training class, listens intently to lecture regarding one of systems in Convair 880.



This 1/4-scale model can be disassembled for study of cockpit furnishings and instruments.

Supplementing both the ground and flight courses and linking the two together into a thorough course of indoctrination is a large and valuable training aid — the cockpit procedures trainer. Although costing over a quarter million dollars, the cost of one hour's instruction in the trainer is negligible as compared with one hour in the "880."

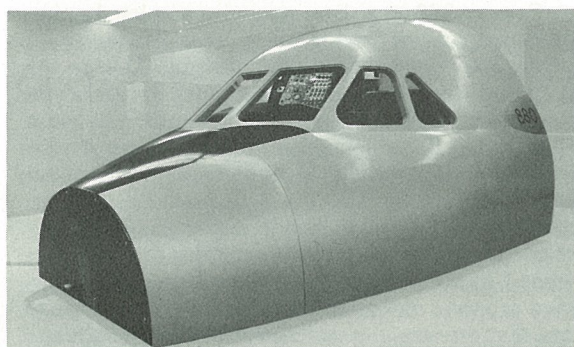
Manufactured by Burton Rodgers Inc. of Cincinnati, Ohio, the "880" cockpit procedures trainer is an exact duplicate of the "880" airplane cockpit section with the exception of an added control panel for the trainer instructor. The trainer is specifically designed to acquaint flight personnel with the actual procedures involved in flying the "880." All operational conditions can be simulated except flight attitudes and related navigational problems. All cockpit controls which directly or indirectly affect the simulated information presented are both physically and functionally operative. The remaining controls, although functionally inoperative, are realistically mocked-up in respect to feel and movement.

The engine and aircraft systems instruments in the trainer respond automatically to operation of the pilot, copilot, and flight engineer controls. Cockpit procedures for ground checks, takeoff, climb, cruise, landing, and emergencies can be practiced by flight personnel until they are thoroughly familiar with them.

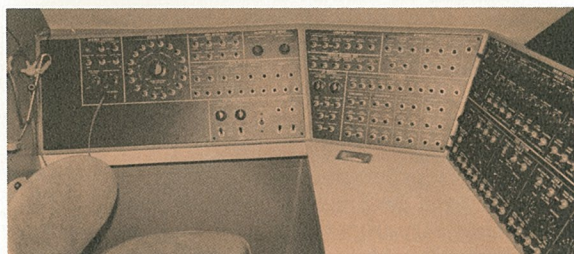
Normal function of the cockpit instruments in the trainer can be interrupted at any time by the instructor. He has a large array of knobs on his control panel with which he can provide inputs to, override, or cause a malfunction in any of the pilot's, copilot's, or flight engineer's instruments. This arrangement allows the instructor to construct a variety of problems for student analysis. For example: with the trainer in cruising condition at 20,000 feet (simulated, of course), he can cause one or more of the engines to "flame out," forcing the student crew to execute their appropriate emergency procedures for such an incident. Loss of simulated engine noise would be experienced in this case as well as a drop in tailpipe temperature, fuel flow, and pressure ratio indication. The engine speed would slow to zero if on the ground or to appropriate windmilling speed if airborne.

The following systems, or portions thereof, have been simulated and are operative in the trainer:

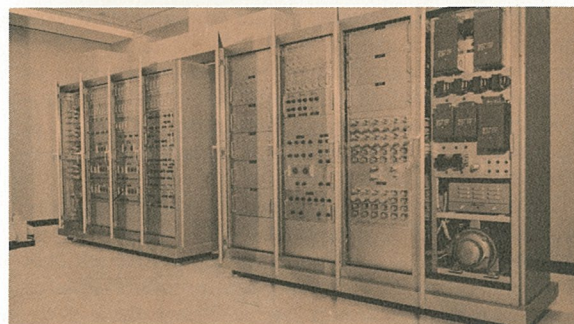
AC Power	DC Power	Lighting
Oxygen System	Power Plant	
Bleed Air & Anti-Ice System		
Air Conditioning & Pressurization		
Fuel System	Hydraulic System	
Intercommunications System		
Fire Detection & Extinguishing	Landing Gear	
Flight & Navigational Instruments (altimeter, airspeed indicator, Machmeter, longitudinal portion of artificial horizon, rate-of-climb indicator, and air temperature gage only)		



Flight procedures trainer is same size and configuration as that of Convair 880 cockpit.



The instructor's station contains a large array of control knobs with which he can provide inputs to, override, or cause a malfunction in any of the flight crew's instruments or controls.



The "brain," which delivers the proper impulses to the Burton Rodgers flight procedures trainer, is contained in this large bank of equipment.

Vertical Tail Proof-Load Tests

... During a nine-month test program, stresses were applied to the airplane in a variety of combinations to simulate flight conditions ...

A Convair 880 jet airliner recently completed a nine-month program of "flying" in a large hangar at the Convair San Diego Ramp Test Facility. During this test period, the airplane was subjected to all of the stresses that would normally be encountered in actual flight. During the nine-month program, these stresses were applied in a variety of combinations to simulate flight conditions.

Purpose of the testing was to insure that the structure of the Convair 880 would meet the stresses it was designed to withstand. From these tests, which permitted accurate measurements, engineers were able to prove that the airplane structure met the strength and deflection requirements of the design.

The airplane used for the tests was Convair 880 ship No. 2, which came off the production line in December 1958. It was structurally complete, but without many of its systems. Engine pods, not needed for some of the earlier tests, were installed later.

One of the most important phases of the proof-load test program was the Vertical Tail Proof Test. For this test, tension pads were attached to the horizontal and vertical stabilizers, locations of the tension pads being established from load calculations submitted by the Engineering Structures Group. These pads were $\frac{3}{4}$ x 5 x 5-inch soft rubber pads, cemented to the surface with $\frac{1}{8}$ -inch steel plates vulcanized on the outer surface. Eyebolts through the steel plates (with swiveling nuts) transmitted the individual pad pulls to a whiffletree arrangement of levers connected to hydraulic cylinders. The whiffletrees, similar to the pivoted bars between a horse and wagon, were "stair-stepped" one atop another to a single large whiffletree attached to hydraulic load cylinders. These were special long-stroke cylinders with varying load capacities, the maximum being 200,000 pounds. Maximum working pressures were held to 3,000 psi.

The whiffletree load distributing arrangements were constructed of aluminum alloy channels, arranged in pairs to provide a double shear action through AN bolts at the pivot joints. The use of aluminum alloy for the whiffletree levers greatly facilitated these tests. They provided a considerable reduction in weight with consequent easier handling and far less time for fabrication. Thousands of the smaller arms were used.

The first of the fin tests was a straight bending load applied only to the vertical stabilizer, to simulate a load reaction that could occur from encountering a gust. This is the maximum torsion and side bending on the fuselage. The fin tip was deflected a distance of 15.0 inches under maximum load, and returned to normal when the load was relaxed.

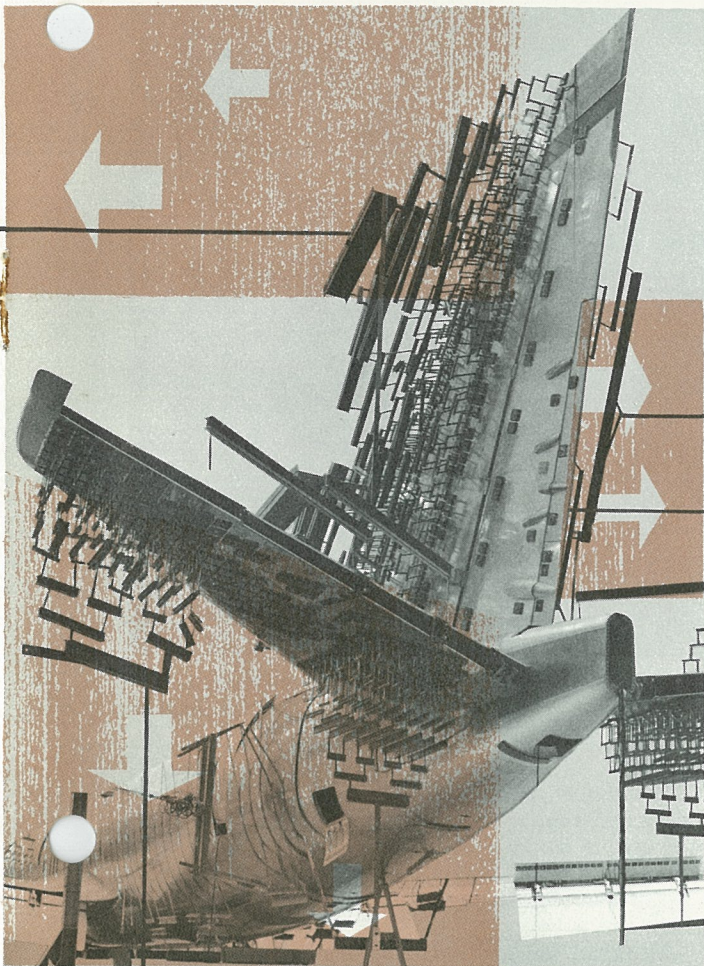
The fin torsion test also involved a cumulative total of load conditions ... application of full design limit loads to the vertical stabilizer in one direction; application of opposite loads on the rudder; dynamic pressure loads on the rudder balance boards; loading from a payload of passengers and cargo (simulated). All of these loads were assumed to be occurring at once.

The structure involved under these loads was tested for three separate conditions. One of these was to design limit load with the fuselage pressurized to 8.6 psi. This is the maximum pressurization relief valve setting. The second test to design limit loading was made without pressurization, but with doors and windows closed. The third test was made with all doors open. Pressurization actually assisted the fuselage structure to withstand the loads imposed. The internal pressure had a tendency to retain normal shape of the fuselage. When the air pressure was equalized as in the second test condition, this form of "strengthening" of the fuselage structure was removed and the reliance was on structural strength.

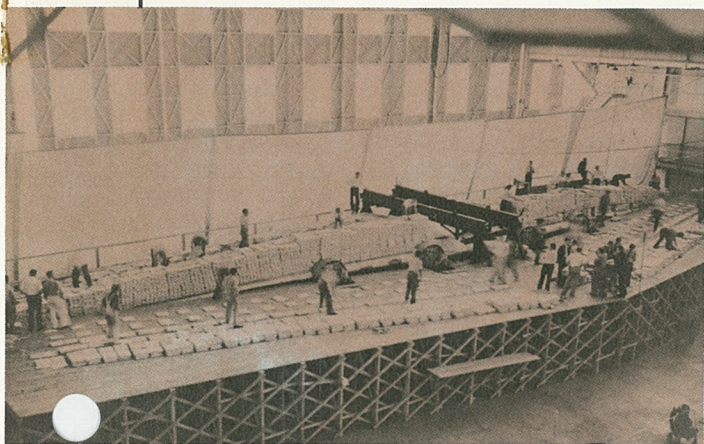
Under each of these three severe proofing loads, the fuselage displayed some temporary wrinkles. This was natural and as expected, yet the wrinkles were considerably less than those observed on other occasions during the testing of conventional fuselage structures.

Doors were opened and closed both before and after tests to demonstrate their proper functioning. Deflection under such loading is proportional to the load as long as the elastic limit of the material is not exceeded; otherwise, a permanent deformation will result. Upon removing these high loads, no permanent deformations were observed which would not be compatible with full safety of the structure. The maximum deflection recorded during these torsional tests was 1.65 inches measured at the fin tip.

For the fin tests, the airplane was supported as a free body in a balanced state, and reaction loads were



View of Convair 880 vertical tail showing how simulated flight loads were distributed by means of rubber pressure pads attached to whiffletree pulling arrangement. Whiffletrees are connected to hydraulically-actuated loading cylinders.



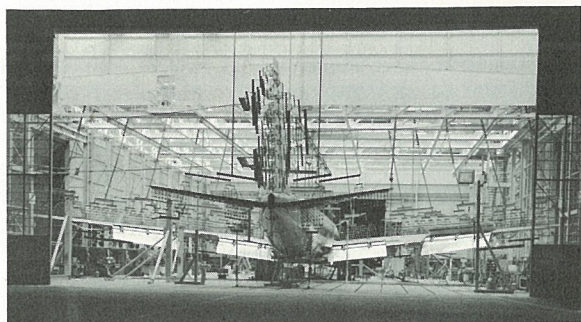
Shown is method of applying proof loads in 1939. A crew of approximately 50 strong men applied a "dress rehearsal" 40-percent proof load, then followed it up by the full loading and unloading of 50 tons of sandbags. XPB2Y-1 wing stood up under the loading.

introduced as "live" loads. Net loads were applied with directional components normal to the manufacturing chord plane in the limit load position. In the vernacular of the structures test engineer, the airplane was "flown" in the test facility. The airplane structure, in addition to being in a balanced load state, was suspended to eliminate possible reaction from ground loads. This was augmented through the dead weight relief system. When suspended in this manner with high test loads applied, it is conceivable that a structural failure, a supporting or test fixture failure, or inadvertent overloading could occur. In this event the airplane could move within the facility with considerable violence with resultant damage to the aircraft. To preclude damage of this nature, complete snubbing (energy absorbing) systems were used to restrain the airplane.

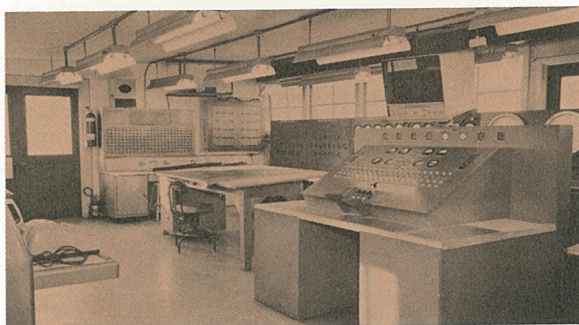
The test facility designed for this type of work was capable of reacting large loads in all directions. The floor of the structure is comprised of slabs of reinforced concrete three feet thick, traversed with steel channels capable of withstanding a pull of 11,000 pounds per running foot. The overhead structure is also designed for supporting high loads. Ultimate loads which would be imposed in testing the "880," however, were quite high, and the building was actually checked by applying hydraulic loads between the floor and the overhead structure prior to arrival of the "880," so as to insure that the structure was adequate for performance of the proof-load tests.

To get the airplane into the building it was necessary to cut out portions of the building on each side between the main roof columns, since the "880" wing span exceeds the width of the test facility. To position the airplane it was necessary to diagonally maneuver one wing through one of the openings until the opposite wing tip cleared the opposite wall. Then the airplane was sidled into position so that it was centered within the building. To accomplish this maneuver, it was necessary to apply copious quantities of a soap solution to the floor, which permitted "sliding" the airplane into position.

All hydraulic loading, control lines, and electrical wiring were routed to an adjacent building from which the tests were controlled. Actuating lines were routed from hydraulic jacks to four Edison load maintainers



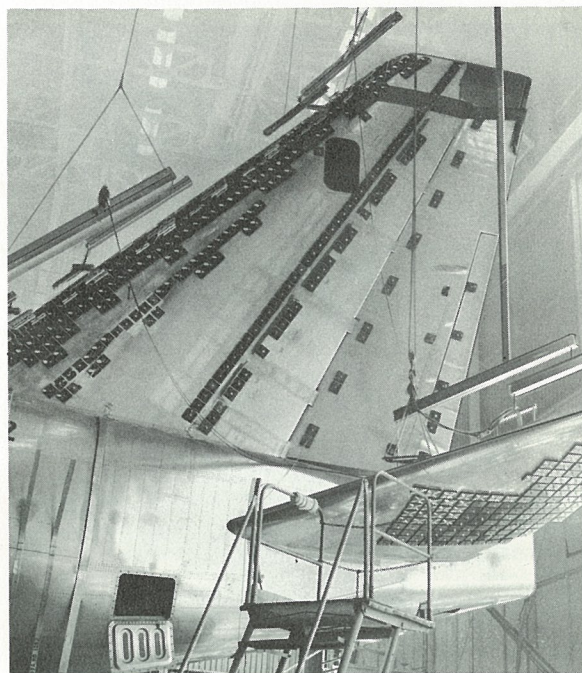
Convair 880 in test facility with pressure pads and whiffletree loading devices attached, preparatory to extensive proof-load testing.



Remote control room of Ramp Test Facility. Master control console is in foreground. Closed circuit television screen above console is connected to camera inside test facility.

in the remote control room. Each maintainer accommodated ten outlets to individual loading jacks, and controlled the accuracy of the loading to $\frac{1}{2}$ of 1 percent. The hydraulic arrangement used was a quick response system so that loads reached a preset pressure on all parts of the system simultaneously and could be relieved as quickly.

In the remote control center were installed two Beckman, 200-channel automatic strain gage recorders. These recorders were capable of recording information from a full complement of strain gages in three minutes. Large deflections were read through a remote indicating device, consisting of Autosyn motors to which



"880" tail showing attachment of tension pads. Location of pads was established from load calculations submitted by Structures Group.

an accurately threaded metal spool was attached. A linear, differential transformer type transducer system was used to measure deflections up to 1.0 inch with an accuracy of ± 0.002 . This system utilized a direct-reading printer with a capacity of 100 deflection point channels.

An initial run on each individual test was made at 40% load to assure that the apparatus was functioning properly, and as a briefing run for the test crews. Proof loads were made in progressive increments of 10 percent of the maximum load (100 percent of design limit). A complete record of strains, deflection of structure, and amount of slippage, or set, which occurred at certain structural connections under load, was thus obtained.

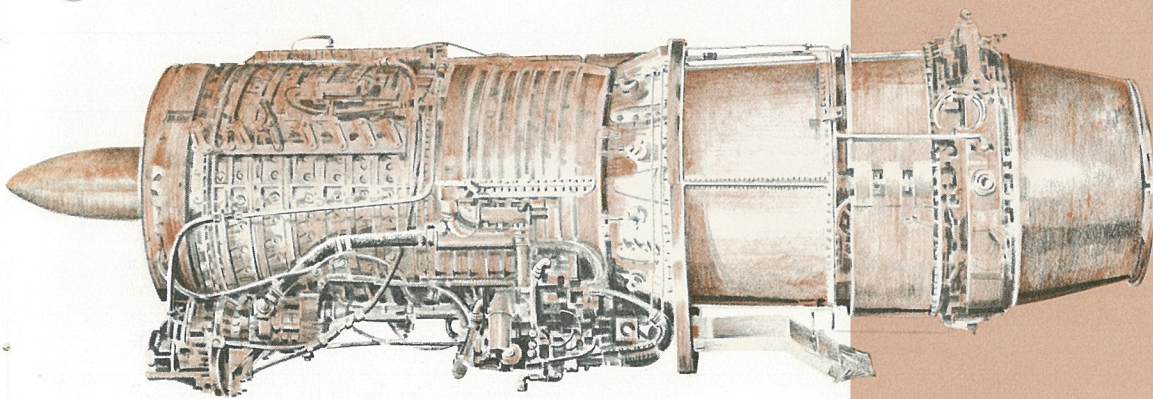
Although these tests were among the most rigorous to be applied in the long list of structural proof-testing and could be regarded as a spectacular demonstration of strength, engineering regarded them as simply a confirmation of the design by stating that the fin torsion tests were satisfactorily completed. It is interesting to note that the most critical test was that in which the cumulative load conditions were applied with the fuselage doors open and the airplane structure unpressurized. The structure withstood this critical test without difficulty. In normal operation, the airplane's demonstrated strength would be augmented by the closed cabin doors, and most probably by the pressurization as well.

Following completion of tests, the No. 2 airplane was returned to the factory for completion of its interior, installation of hydraulic, pneumatic, and electrical systems, and prepared for service as a flying airplane.

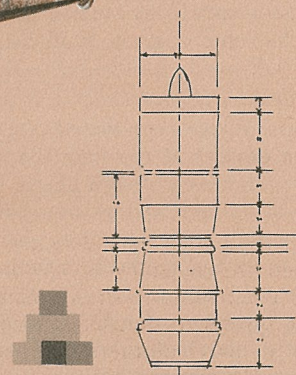
Design Features of CJ 805-3 Engine

The General Electric CJ805-3 engine used in the Convair 880 airplane is a single-spool, axial-flow, high-pressure-ratio turbojet providing excellent takeoff and cruise performance, light weight, simplicity of design, and ease of maintenance and overhaul. These features were in effect designed into the CJ805-3 engine at the time work was started on the J79 military engine several years ago. This article discusses the original J79 design program, and the steps that were taken to develop the CJ805-3 commercial engine.

One of the most important requirements for good cruise performance in a jet engine is high compressor pressure ratio. As methods of achieving high pressure ratios have been developed over the years, corresponding improvements in cruise fuel economy have been obtained. Doubling the pressure ratio can reduce the cruise specific fuel consumption of an engine by as much as 15% to 20%.



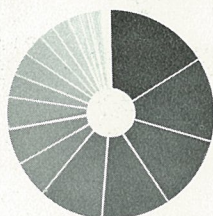
This article was prepared for the Traveler by R. E. Weymouth, Applications Engineering, Commercial Engine Operation, General Electric Company. It explains basic design considerations that established the distinctive characteristics of the CJ805 engines which power the Convair 880 and 600 jet airliners.



There are several ways of achieving high pressure ratio. Increasing the rotational speed is one. Another is to add a large number of individual stages or rows to the compressor. A third involves the use of higher blade loadings in each stage. There are certain problems associated with each of these approaches and, as a result, the final design is usually a combination of all three. The objective is to achieve high pressure ratio with minimum engine weight, length, and complexity and, of course, to stay within the state-of-the-art technology.

To obtain a high pressure ratio compressor in a reasonable size, today's jet engines must use a variable control of the flow of entering air so that the high-pressure end of the compressor can satisfactorily handle flow at all operating conditions, particularly during acceleration and deceleration. Otherwise, a phenomenon known as compressor stall may occur, seriously affecting engine performance. Individual compressor blades are airfoils and, in order to compress the air efficiently, the blades have high camber. Flow separation can take place and the compressor may "stall," much as a wing stalls at too high angle of attack.

Among the approaches to the problem of flow separation used today are: 1) variable stator vanes, 2) dual



INCREASING ROTATION SPEED



ADDING INDIVIDUAL STAGES



HIGHER BLADE LOADING

rotors, and 3) bleed valves. In variable stator engines, the early stage vanes are rotated to reduce and direct airflow during transient conditions. With dual rotors, the front section operates at varying speed relative to the rear section. Bleed valves may be located in the compressor section to remove excess air during transients. In some engines, both dual rotors and bleed valves are used to achieve satisfactory transient operation.

General Electric conducted extensive studies of each of these devices at the time the military J79 engine was in preliminary design phase. It was decided that the use of variable stators would make possible lower weight with greater simplicity than would other variable flow control methods. Extensive testing has now supported this conclusion. The CJ805-3 ease of maintenance, minimum number of major components and maximum interchangeability of parts, and its minimal manhour requirement for overhaul can all be attributed to the selection of the variable stator principle.

It should be pointed out that the variable stator mechanism is in use only when the engine is accelerating or decelerating, and not at over 93% rpm. The vanes are locked in position during cruise, climb, and takeoff rpm.

Detailed comparative studies of a variable stator engine and a dual rotor engine have consistently shown that, for the same size engine, lower weight can be expected with the use of the variable stator. In addition, however, there are other features in the CJ805-3 engine which contribute to its low specific weight. One of these concerns the compressor radius ratio. Radius ratio is defined as the ratio of wheel radius to blade tip radius.

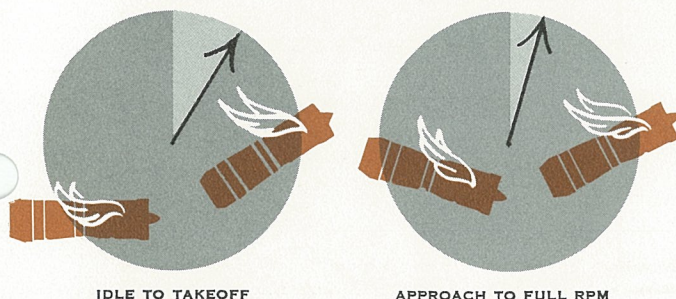
To make the most efficient use of the available space within the specific engine diameter, the desirability of minimizing wheel diameter becomes apparent. The reason for this is that the area described by wheel diameter is not in itself contributing to the performance of the engine. The radius ratio of the CJ805-3 engine is 0.34; that is, the wheel radius is about one third of the compressor blade tip radius. Thus, it is possible to pump the same volume of air through a smaller overall diameter engine. And, as engine diameter decreases, engine weight is lower, and aerodynamic resistance is less.

Another feature of the CJ805-3 engine, which contributes to its low weight, is the use of conical shafting. For example, the conical drive shaft that connects the compressor to the turbine has the necessary rigidity and strength with a minimum of weight.

In comparing the operating conditions of the military J79 with the commercial version, it is obvious that the military requirements are much more severe than are the conditions encountered during commercial operation. The important engine parameters of temperature and pressure are all higher in the J79 engine, which was designed for use at supersonic speeds. The "G" loadings and gyroscopic load requirements in the military specifications are much more severe than are those for a commercial engine.

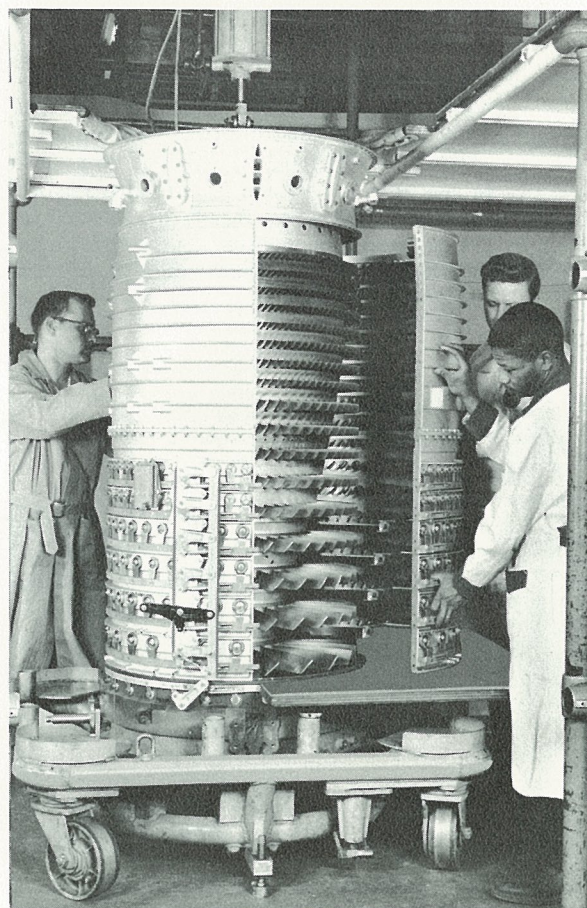
The natural tendency might be to prune weight from a military engine when it goes into commercial service. Such was not the case in converting the J79 engine into the CJ805-3. As a matter of fact, the weight (less afterburner) was increased by over 10% to insure a long-life rugged engine for commercial use.

One important characteristic made possible by the light weight of the CJ805-3 engine is the very low acceleration time. The weight of the rotating compressor-turbine combination has much to do with the speed of acceleration because of the amount of inertia to be overcome. The CJ805-3 engine can accelerate from idle to takeoff power in only five seconds. It takes



about half this time to accelerate from approach rpm to full power. The control system on the engine has been designed so as to make such accelerations possible without concern for "over-temperaturing" the turbine or "stalling" the compressor. One consistent comment from all who have operated a CJ805-3 has been its excellent throttle response.

The CJ805-3 engine is essentially an all-steel engine. Except for the use of magnesium castings in the front frame and in the gear casings, steel is used throughout in the major components. There is a large variety in the type of steel used, depending upon the operating temperatures and stresses. In the relatively cool compressor portion of the engine, low alloy steels, suitably protected against oxidation and corrosion, are used for the compressor discs, casings, and frames. A high strength corrosion-resistant steel, containing about 12% chromium, is used in the compressor blades and vanes. As temperatures increase in the combustion and turbine sections, it is necessary to use heat-resistant materials. The first stage turbine buckets, which are exposed both to fairly high temperatures and rotative speeds, are precision cast using a high-strength nickel base alloy. The second and third stage buckets use M252, a General Electric-developed nickel base material first used in the J47 engine.



Casing halves can be removed singly for inspection without complete disassembly of the engine.

It is of interest to point out that no titanium alloys are used in the CJ805-3 engine itself. Also of interest is the fact that no aluminum has been used in any of the major components.

Extreme care has been used in laying out the cooling system for the turbine area so as to reduce temperatures as much as necessary with a minimum amount of cooling air. Since this air is taken from the compressor, it is mandatory to keep the use of bleed air to a minimum.

Another feature that has been incorporated in the design of the engine is the use of horizontal split casings around the compressor, combustion, and turbine sections to enable quick inspection and repair. The CJ805-3 is a three main bearing engine, which greatly simplifies the lubricating system, eliminates problems of excessive temperatures and oil consumption, and reduces overhaul manhour requirements.

The CJ805-3 engine is a design resulting from General Electric experience with eight types of jet engines, and a total production history of over 32,000 engines. The features incorporated in the CJ805 have come about as the result of a thoroughly planned and carefully executed design program, backed by years of experience in design, production, and service of jet engines.

Convair 880 jet airliner being prepared for proof-load testing of the empennage. For these tests, tension pads were attached to the horizontal and vertical stabilizers. Whiffletrees, similar to the old-fashioned hook-up between horse and wagon are stair-stepped, one atop another, to a single large whiffletree, which is attached to a hydraulic ram. When the ram is contracted, it pulls the affected surface, the whiffletree arrangement spreading the stress over a large area to simulate the stresses that would be encountered in actual flight of the "880."



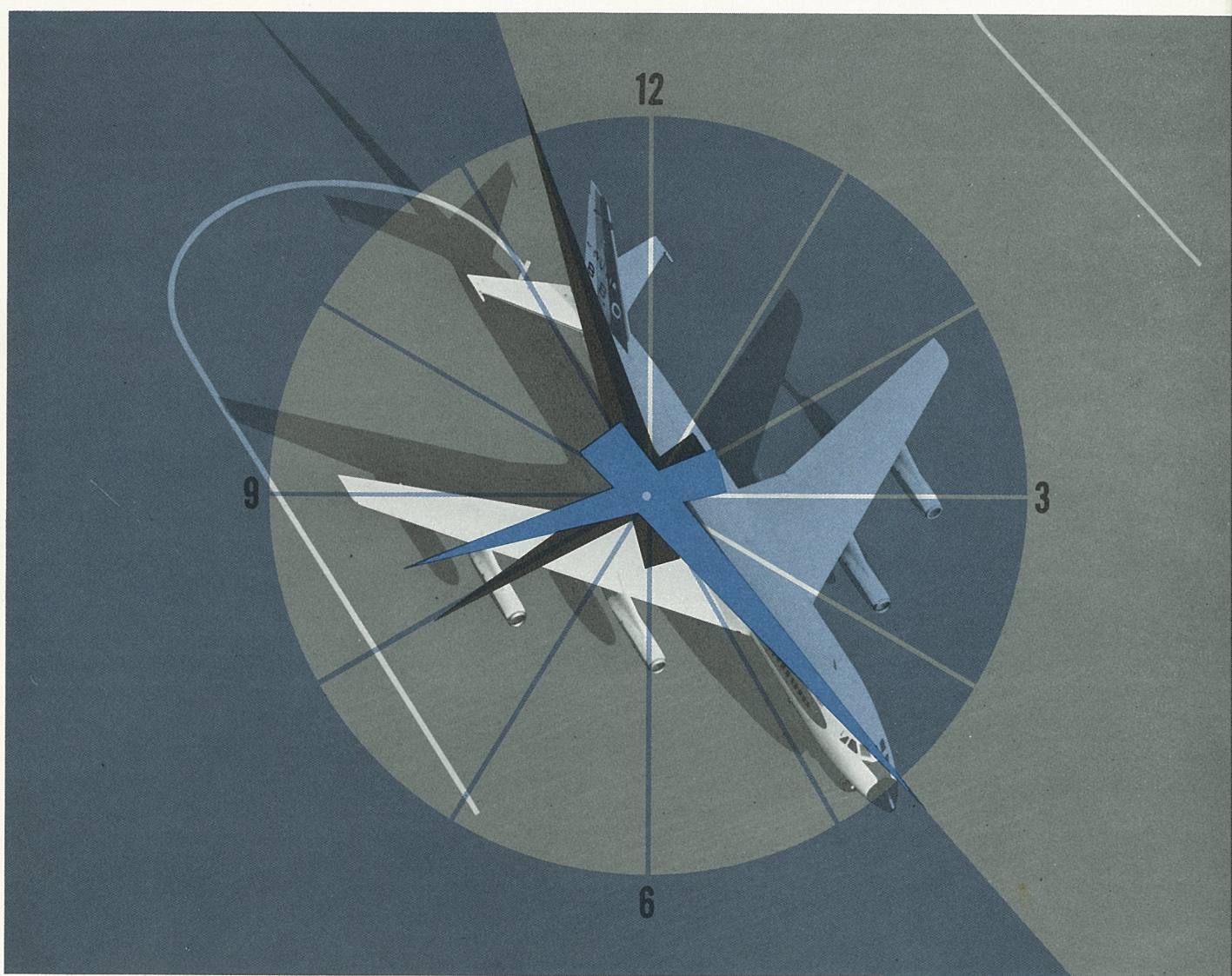
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CONVAIR DIVISION

GENERAL DYNAMICS CORPORATION

VOLUME XI NUMBER 5 SEPTEMBER 1959

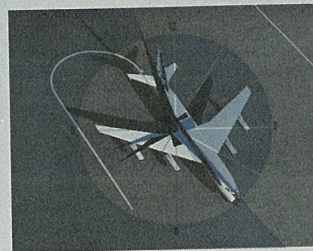
Convair Traveler



In this Issue: Servicing the Convair Jet Airlines

VOLUME XI NUMBER 5 SEPTEMBER 1959

Convair Traveler



In this Issue: Servicing the Convair Jet Airlines

OUR COVER

The clock never stops for operators of commercial transports. Minutes saved are dollars — on the ground and in the air. Convair jet airliners lead, both in block time and in speed of servicing and maintenance.

The artist— George Paul

Convair Traveler

VOLUME XI NUMBER 5 SEPTEMBER 1959

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FUEL JETTISON TESTS

N. V. Davidson

A digest of operation and service published monthly by the Service Publications Sections of Convair Customer Service Department in the interest of Convair operators. Communications should be addressed to the Manager of Customer Service Department, Convair, San Diego 12, California. Information is to be considered accurate and authoritative as far as Convair approval is concerned. FAA approval is not to be implied unless specifically noted. Recipients of this information are cautioned not to use it for incorporation on aircraft without specific approval of their cognizant organization.

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Servicing the Convair Jet Airliners

to meet demands of competitive scheduling – jet transports must be designed to permit efficient servicing operations



By the time the Convair 880 and 600 aircraft go into regular service, many of the world's major airports will be equipped for handling large jet airliners and will have had experience in their servicing. To such airports, the "880" and "600" will present few new requirements.

The Convair transports will, however, be serving airports where the larger jets now flying do not often land. Type of fuel, hydraulic fluid, and lubricating oil will differ from that required for most propeller aircraft. Jet engines, unless the airplane is one of the few with a self-contained starting system, all require a source of pneumatic power for the turbine starters. Ground air conditioning requirements for transports the size of the Convair jet airliners are greater. External electric power is a-c, and loads are larger than in piston-engine transports.

Another aspect of jet airplane servicing is the urgency to save time. Besides the matter of passenger convenience in making stopovers brief as possible, an idle jet transport is costly. Turnaround and maintenance time must be kept to a minimum.

Expediting servicing and maintenance has been a prime objective through all design stages of the Convair 880 and 600. Engineering groups were charged with seeing that the airplane's major systems are quickly accessible, easily serviced with minimum special ground support equipment, with components quickly replaceable when necessary.

Ground service points are located so that normal servicing operations can be conducted simultaneously, without inconvenience to passengers, from the instant the airplane rolls up to the ramp until it is ready to leave. The forward lavatory service panel is the only turnaround service point on the left-hand side of the

fuselage; buffet, electrical, air and water carts will be on the right-hand side. All fuselage service panels except the lavatory can be reached by a man standing on the ground.

Air conditioning, pressurization, and hydraulic systems will normally require only inspection for leakage and fluid levels. Emergency equipment—passenger oxygen cylinders and fire extinguishers—need replacement only after use or after prescribed time lapses. Engine pod doors will usually not be opened on a turnaround; lubricating oil tanks can be serviced through an access door in the upper pod structure. The only other engine point that might require servicing during stopover is a fuel drain tank that should be drained after two unsuccessful engine start attempts.

Refueling is most rapid and most convenient through pressure fittings, two on the under surface of each wing. Gravity fill connections are also provided on the upper surfaces. There are no walkways on the wing; design is such that the wing box section can be walked on if proper precautions are taken against marring the surface.

Water and lavatory fittings are standard. Cleaning equipment, passenger ramps, and cargo handling and galley service equipment will be like that presently in use for passenger transports. The differences that may arise will be only those associated with the fact that "880"- "600" aircraft are larger, and stand higher, than most propeller-driven transports.

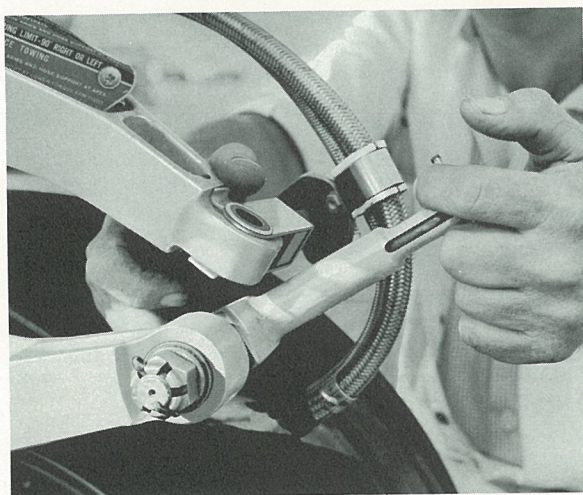
The following pages contain illustrations and more specific lists of requirements for routine servicing of the "880" and "600". In the Traveler for April 1959, dimensions and locations and heights of service points of the "880" were given in detail. Equivalent information for the "600" is presented on Pages 12 and 13.

Convair-built towbar has pins that slide into cups at ends of axle. It is held in place by T-handle lockpins. The airplane may be either pulled or pushed.

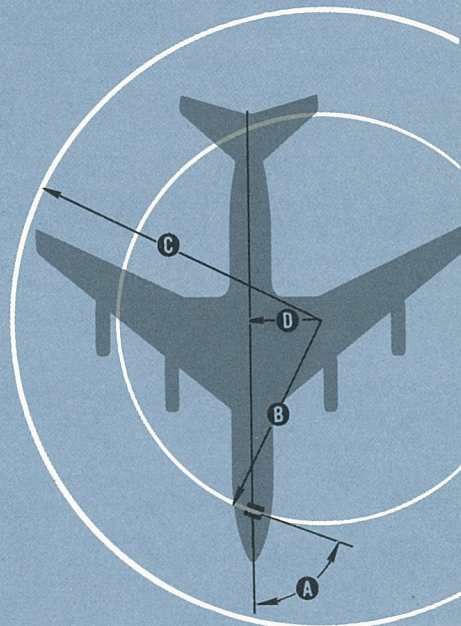
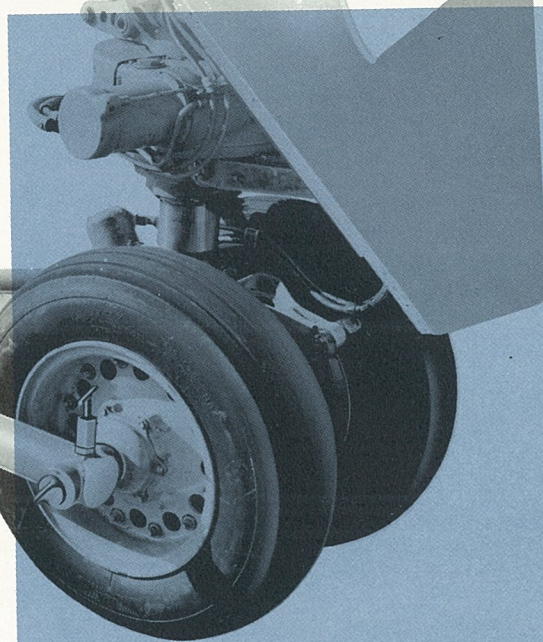
Towing from the nose gear requires a forked towbar with pins to fit into cups in the ends of the co-rotating nose wheel axle. Maximum pull or push between straight ahead and 45° ("880" only) is 27,000 lb; side load component (at 90°) should not exceed 20,000 lb. Nose wheel steering may be disconnected by pulling a pin at the apex of the torque links. A 360° turn is possible only if brake lines are also disconnected.

The airplane may be towed by cable from lugs on forward and aft ends of the main gear trucks. Pull limit ("880") is 20,100 lb on each gear within 30° of the truck beam axis. This method, requiring two tractor units in close coordination, can be utilized in mud, snow, or over rough terrain.

The airplane can be moored at the nose gear and by use of the towing lugs on the main trucks. Experience has been that aircraft heavy as the Convair jet airliners require mooring only in extraordinary storm conditions. Control surfaces are always protected by the gust dampers.



Quick disconnect pin releases nose gear torque link and hose support, allowing sufficient turn angle for normal towing operations at airport.



TURNING RADIUS

	880	600
A Maximum turn angle	70°	68°
B Minimum turn radius	56' 9"	61' 11"
C Wingtip clearance radius	84'	87' 11"
D Pivot point BL at MLG CL	19' 5"	23' 2"

JACKING 880

Landing gear jack pads are located under nose and main gear struts, and under main gear axles. A jack for the nose gear or for one main gear axle should have a 25-ton capacity, 5-inch maximum width, 7-inch minimum height, 3-inch screw extension, and 12-inch lift. Jacks to raise a main truck at the center jack pad should have a 50-ton capacity, 7-inch maximum width, 8-inch minimum height, 3½-inch screw extension, and 9-inch lift. For use with electronic weighing cells, minimum heights should be an inch less.

Wing jack joints will be at 91-inch minimum height with all four tires on one truck deflated; the fuselage nose jack point, with both nose tires deflated, will be at 65-inch minimum height. Approximately 26 inches extension of wing jacks would fully extend the strut and lift the tires clear of the ground, and approximately 22 inches extension at the nose jack. The struts may, however, be compressed by external means before jacking. Maximum load at normal CG limits on wing jacks, at maximum landing weight of 132,800 lb, is 64,000 lb, and at the nose jack 12,000 lb.

GROUND AIR CONDITIONING 880/600

With engines shut down, conditioned air can be supplied directly to the airplane without using the airplane Freon systems. Requirements are a unit supplying a maximum airflow of 160 lb/min at a maximum pressure of 1 inch Hg, maximum temperature 130° F, minimum temperature 32° F, designed to operate at ambient temperatures from -40° F to 99° F. Nominal cooling rate should be 25 tons, heating rate 400,000 BTU/hr.

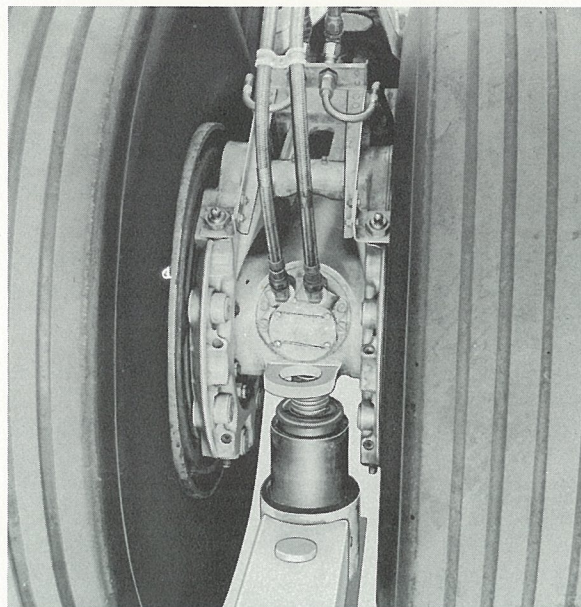
ELECTRIC GROUND POWER 880/600

The airplane a-c current requirement is 120/200-volt, 400-cycle, 3-phase, 4-wire, Y-connected, 0.8 lagging power factor. For aircraft with electrically-operated air conditioning systems, the unit should have a thermal rating of 125 kva; for other aircraft, 65 kva.

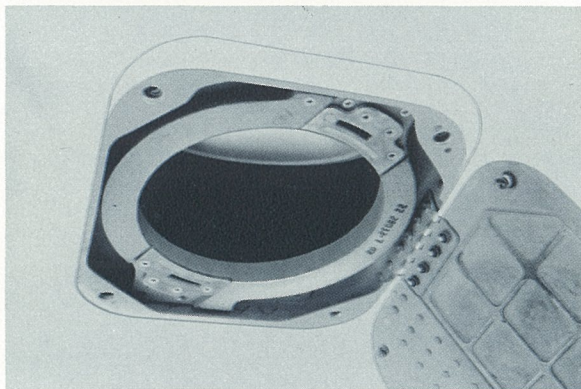
The 125-kva unit should be capable of providing power in the following steps: Upon a preload of 15 kva at 0.8 power factor applied initially will be superimposed a 420-ampere, 0.2-power-factor motor inrush for 1.75 seconds. After a minimum 1-second delay, with unit under maximum preload of 55 kva at 0.8 power factor, a second motor inrush of 270 amperes at 0.2 power factor will be applied for 3 seconds.

The 65-kva unit should be capable of providing power as follows: Upon a preload of 15 kva at 0.8 power factor applied initially will be superimposed a 200-ampere, 0.2-power-factor motor inrush for 1.75 seconds.

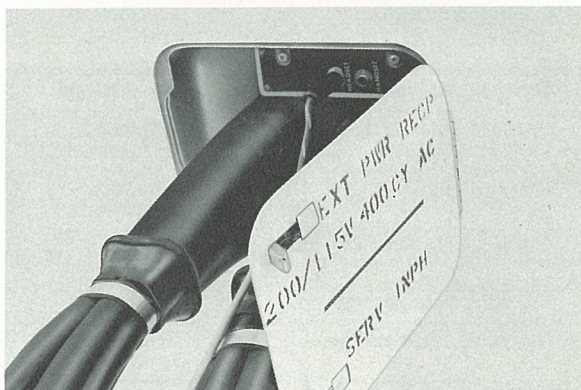
In both units, upon application of the loads described, output voltage should recover to and remain with ±2% of regulated voltage in a maximum of .15 seconds. Maximum output voltage dip should not exceed 41% of the regulated value. Units should be capable of delivering 300% current into a sustained 3-phase short circuit for 6 seconds without overheating or mechanical damage.



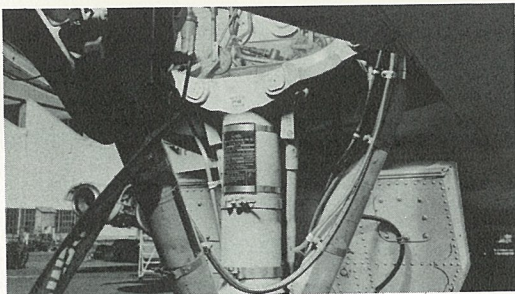
Jack of 25-ton capacity may be used on nose gear or on main truck axle, as shown. Eye may be used for towing or mooring, if necessary.



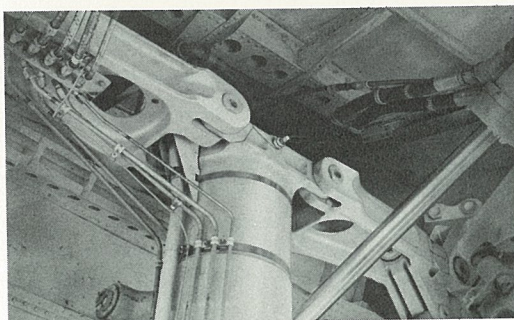
Conditioned air may be pumped directly into "880" air conditioning system through fitting on right-hand side forward of wing leading edge.



External power receptacles may be single, or dual units. The "600" Model 30-5 has extra receptacle near nose gear for use while towing.

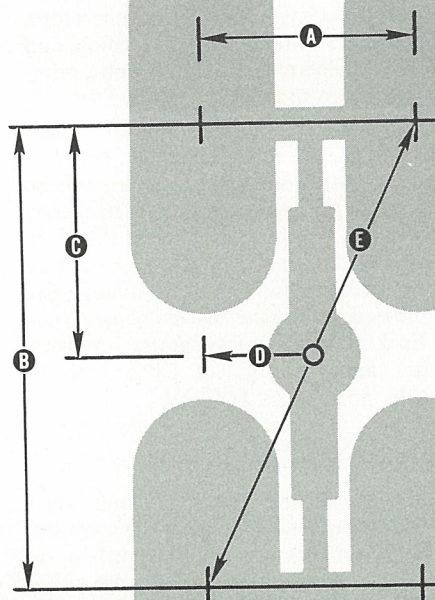


Instructions for servicing nose gear strut appear on placard. Air fitting and gage for brake flask are inside door frame, upper right (not visible).



Air fitting for pressurizing main gear strut is shown at top. Placard (on other side, not shown) gives strut extension with airplane fully loaded.

Landing Gear



MAIN GEAR TRUCK DIMENSIONS

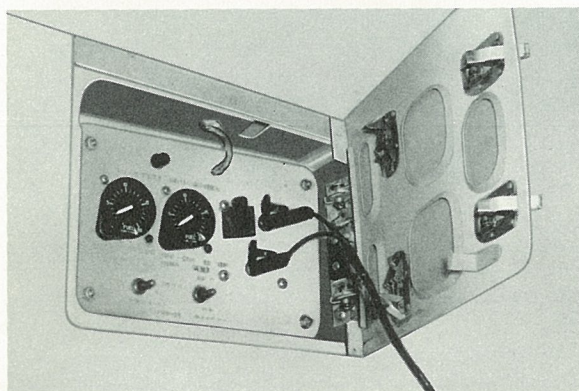
MODEL	DIMENSIONS				
	A	B	C	D	E
880 all versions	21.5	45.0	22.5	10.75	49.87
600 all versions	24.0	46.5	23.0	12.0	52.32

High-Pressure Pneumatic Table

UNIT	LOCATION OF FITTING	UNIT CAPACITY		PRESSURE	
		880	600	880	600
Emergency air brake bottle	Nose wheel well	400 cu in		220 psi	
Hydraulic system accumulators (2)	Hydraulic Compartment	100 cu in each		900 psi	
MLG accumulators (2)	Hydraulic Compartment	400 cu in each		900 psi	
Anti-skid brake modulator	Hydraulic Compartment	50 cu in		250 psi	
NLG strut, static position	Top of strut	71.5 cu in		1180 psi	1070 psi
MLG struts, static position	Top of strut	234 cu in each	—	1712 psi	1994 psi
MLG truck positioners	Aft end of truck	17.5 cu in each		995 psi (with weight off MLG trucks)	

Analysis of Wheel Loading

	880	600
LOADING CONFIGURATION:		
Maximum ramp weight	185,000	239,000
Maximum takeoff weight	184,500	238,200
Maximum landing weight	132,800	180,000
TIRE SIZE AND PLY RATING:		
Nose	29 x 7.7, 12 PR	29 x 7.7, 16 PR
Main	39 x 13, 20 PR	41 x 15-18, 20 PR
TIRE CONTACT AREA:		
Nose	68 sq in	68 sq in
Main	170 sq in	205 sq in
RATED INFLATION PRESSURE:		
Nose	160 psi	220 psi
Main	150 psi	155 psi
RATED STATIC LOAD PER TIRE:		
Nose	9,800 lb	13,800 lb
Main	22,300 lb	28,600 lb
AIRPLANE STATIC LOAD PER TIRE:		
Most forward CG:		
Nose	7,810 lb	10,450 lb
Main forward truck	20,611 lb	27,262 lb
Main aft truck	21,733 lb	27,262 lb
Most aft CG:		
Nose	5,860 lb	6,560 lb
Main forward truck	21,099 lb	28,235 lb
Main aft truck	22,221 lb	28,235 lb
AIRPLANE TIRE PRESSURE:		
Most forward CG:		
Nose	128 psi	166 psi
Main forward truck	139 psi	148 psi
Main aft truck	146 psi	148 psi
Most aft CG:		
Nose	95 psi	105 psi
Main forward truck	142 psi	153 psi
Main aft truck	149 psi	153 psi
TIRE CONTACT PRESSURE:		
Most forward CG:		
Nose	114 psi	153 psi
Main forward truck	121 psi	133 psi
Main aft truck	128 psi	133 psi
Most aft CG:		
Nose	86 psi	96 psi
Main forward truck	124 psi	137 psi
Main aft truck	130 psi	137 psi



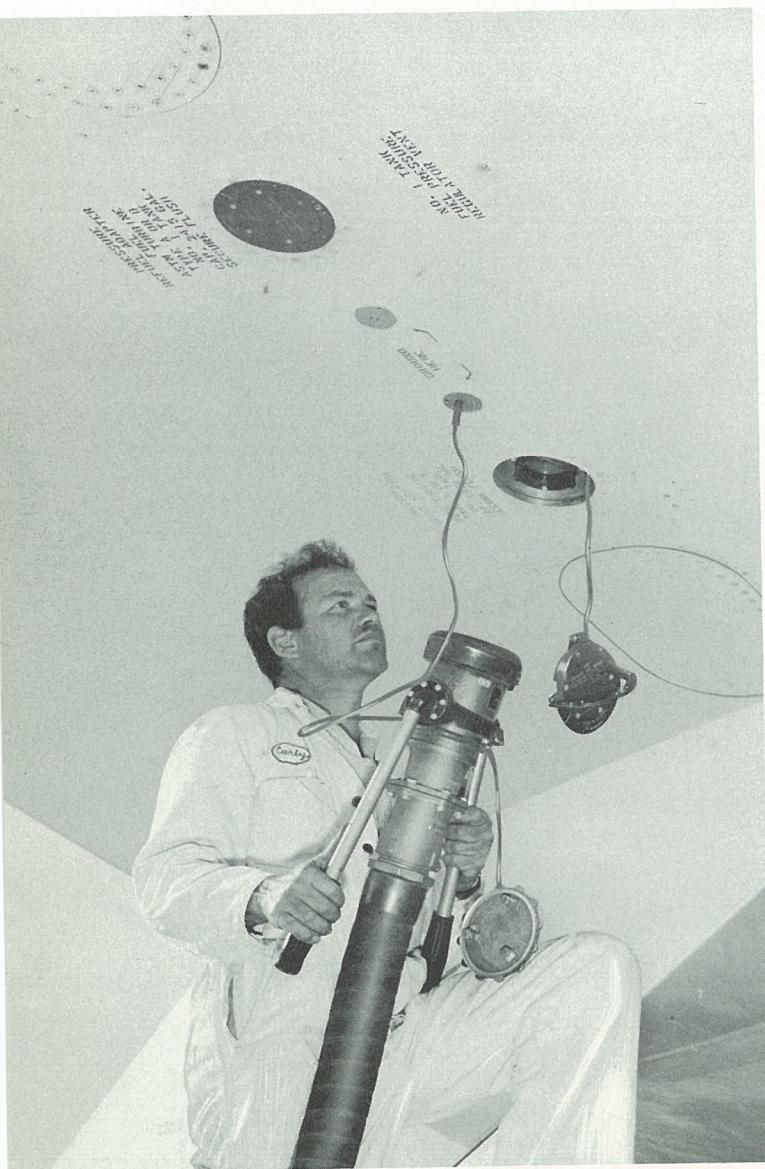
REFUELING 880/600

Total capacity of the "880" wing box section is 10,770 gallons, 2970 gallons in each inboard tank and 2415 gallons in the outboard. Center section fuel tanks in the Convair 600 jet airliners have an additional 3100 gallons. The "600" wings, with the added capacity of the anti-shock bodies, hold an additional 1238 gallons.

Refuel panel on "880" is on outboard side of inboard pylons. On "600," panel is on underwing surface in trailing edge outboard of engines.

The four underwing pressure fittings have a flow capacity of 300 gpm each at 50 psig fuel pressure. Overwing gravity fuel fittings have flush type caps with 3-inch filler necks.

To hold refueling time to a minimum, equipment should have sufficient capacity to service both tanks on each wing simultaneously, pumping 600 gpm at 50 psig.



Inboard and outboard pressure refuel fittings are side by side, outboard of inboard engine on "880," outboard of outboard engine on "600."

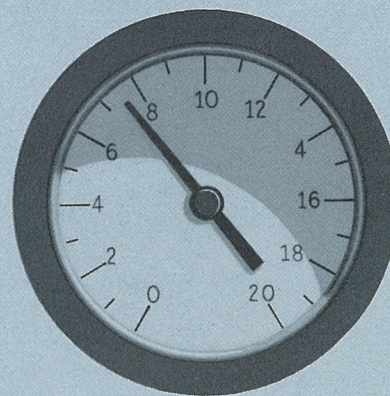
Checking engine oil levels, right, requires a ladder. Engine and CSD tanks have separate dipsticks as well as ports for gravity refilling.

PRESSURIZATION AND AIR CONDITIONING 880/600

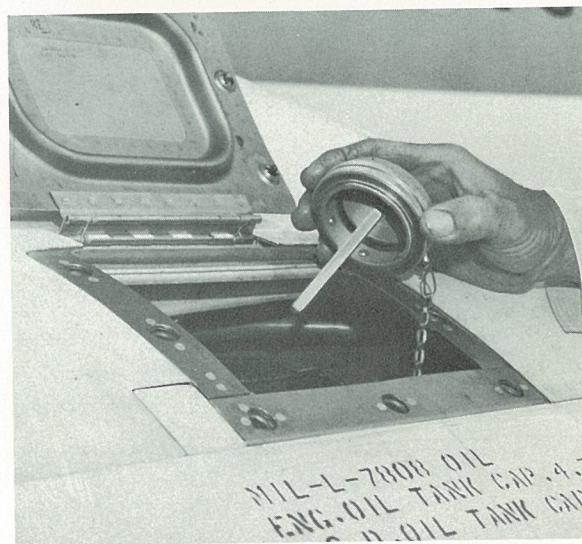
Liquid level sight gages, visible through a porthole in the air conditioning access doors on the bottom of the fuselage, show Freon level. Gages should be read periodically during operation with condenser as cold as possible. If the level is below 4, the package should be drained, checked for leakage, purged, and refilled with Freon to which approximately 5% by weight of lubricant has been added.

Oil level in the turbocompressor should be checked periodically. Level should be above sight line in the gage on the compressor and turbine drive oil sump. If level is visible, oil should be added to the level of the filler plug.

Lubricant specifications are in the fluid table on Page 11.



Freon level gages are on bottom of fuselage. Replenishing freon is lengthy procedure, requiring draining and complete purging of system.



BATTERY 880/600

Since the 27.5-volt storage battery in the "880" and "600" is only standby for use in exceptional emergencies, it requires a minimum of servicing. Rate of charge and discharge, amperage, and voltage can be monitored from the flight engineer's panel. The battery should be inspected every 250 hours of aircraft operation and the electrolyte level checked every 500 hours.

The electrolyte is caustic rather than acid. Hydrometers or syringes used with acid batteries should not be used in servicing nickel-cadmium batteries.

WATER SYSTEMS AND LAVATORIES 880/600

Water capacity of the Convair "880" and "600" is 50 gallons. The service cart should have a pump with a minimum capacity of 10 gpm. Since potable water is required, the cart tank and lines should be corrosion-resistant and suitable for use with water containing 20 parts per million of chlorine.

The lavatory service cart should have a waste tank of 70 gallons minimum capacity and a 20-gallon-minimum supply tank for flushing. The cart should have a platform for standing on; the forward service panel is approximately 7½ feet from ground level. In the "600", the aft panel is even higher, approximately 9 feet 3 inches.

OXYGEN SYSTEM 880/600

Gaseous oxygen is stored in cylinders in the flight compartment, and in portable units in flight compartment and cabin. All cylinders have pressure gages and should be checked periodically and replaced when necessary.

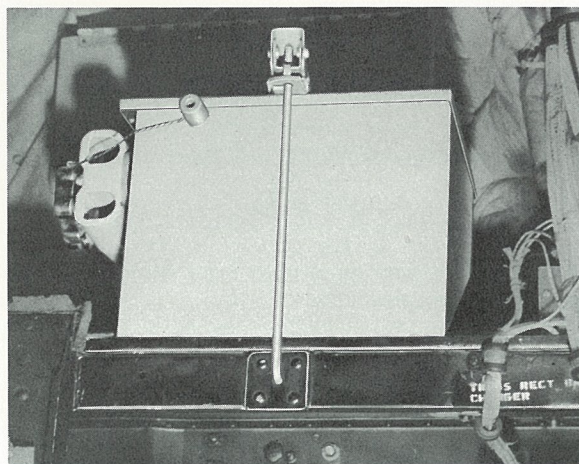
Since one crew member must be on oxygen during high-altitude flight, one of the main supply cylinders will require frequent replacement. The cylinders are lightweight, approximately 9 inches in diameter by 30 inches long, except as noted below. They hold 107 cu ft at 1800 psi. Cylinder and valve assembly is Zep Aero P/N ZC-268-111. Weight fully charged is 44.8 lb.

HYDRAULIC SYSTEMS 880/600

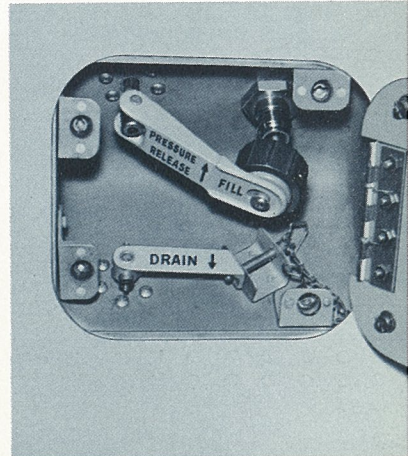
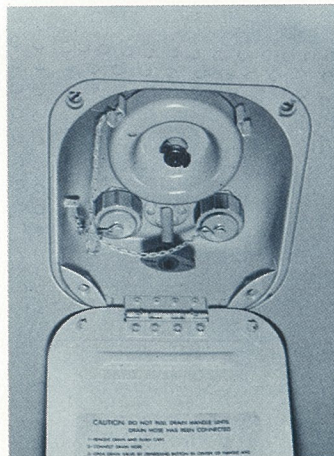
Servicing will not normally be required for hydraulic systems of the "880" and "600" aircraft on stopovers or turnaround. Fluid quantities can be read at the copilot's panel.

If necessary, major system components are accessible through a door on the left-hand side of the fuselage, aft of the wing. System and MLG accumulators are just inside the doors. The emergency air brake flask, in the electrical compartment over the nose wheel well, has its pressure gage and fitting on the nose gear door frame.

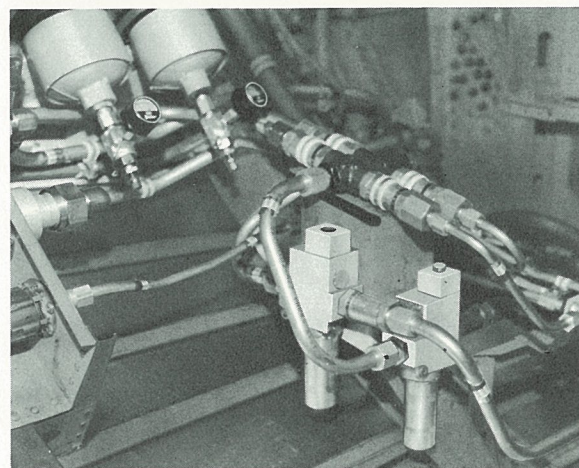
On each "880" pylon are two small transparent windows for checking hydraulic filters. Red pop-up buttons



Battery is on aft face of bulkhead aft of radome. View is from electrical compartment. Normal access is through the top of nose wheel well.



On left is aft lavatory drain; forward drain is on left side of "880," on right side of "600." On right are the water service drain and fill fittings.



View in hydraulic compartment shows main accumulator gages and filters. Button on right has popped out, showing filter that needs servicing.

will be forced out by excessive pressure drop across the filters, to warn when they need servicing. Two such filters, for ground cart or auxiliary pumps, are in the "880" hydraulic compartment.

LOW-PRESSURE AIR 880/600

A ground source of compressed air is necessary to start the engines. It may be used to operate the air conditioning system on aircraft using bleed air as an air conditioning power source.

Requirement is for a flow of 100 lb/min at a pressure of 48 psia under conditions of sea-level ambient pressure, 100° F ambient temperature, and airflow temperature of 435°.

For engine start, some aircraft have connections for using a ground cart in-line combustor on one or both of the right-hand engines. At the higher temperature of this flow, the lb/min requirement is correspondingly lessened.

Below, pressure air line is being connected for engine start. On some "880" aircraft, the air connection is forward at the nose wheel well.



Ground Service Connections 880/600

FITTING	VENDOR P/N OR MIL SPEC
1 Conditioned air (880 only)	MS 33562 ABC Std
2 Gas turbine compressor	Bobrick 914 (conforming to AF Dwg 54 B 9301)
3 Engine start in-line combustor (No. 4 engine Model 22-2 only)	Wiggins GSN-151-C-35D
4 Lavatory service: Drain (880) Drain (600) Flush (880/600)	Roylyn 2651-127D Roylyn 2651-127 Roylyn 1002-16
5 Water system	Roylyn 1002-12C
6 Pressure refuel	Parker 1327-575699 (conforming to MIL-A-7898, Type A5)
7 Hydraulic pressure fill	Aeroquip 305503-S11-6D
8 Hydraulic pressure line	Aeroquip 305503-S11-12D
9 Hydraulic return line	Aeroquip 307012-S11-1D
10 Hydraulic accumulators and brake air flask	MS 28889-1
11 External power receptacle	AN3114-1B
12 Soldering iron receptacle	Hubbell 7332
13 Passenger ramp receptacle	Hubbell 10108
* Interphone: Jacks Boxes	Mallory SCA-28 Mallory SC-1A, Trimm 95-25

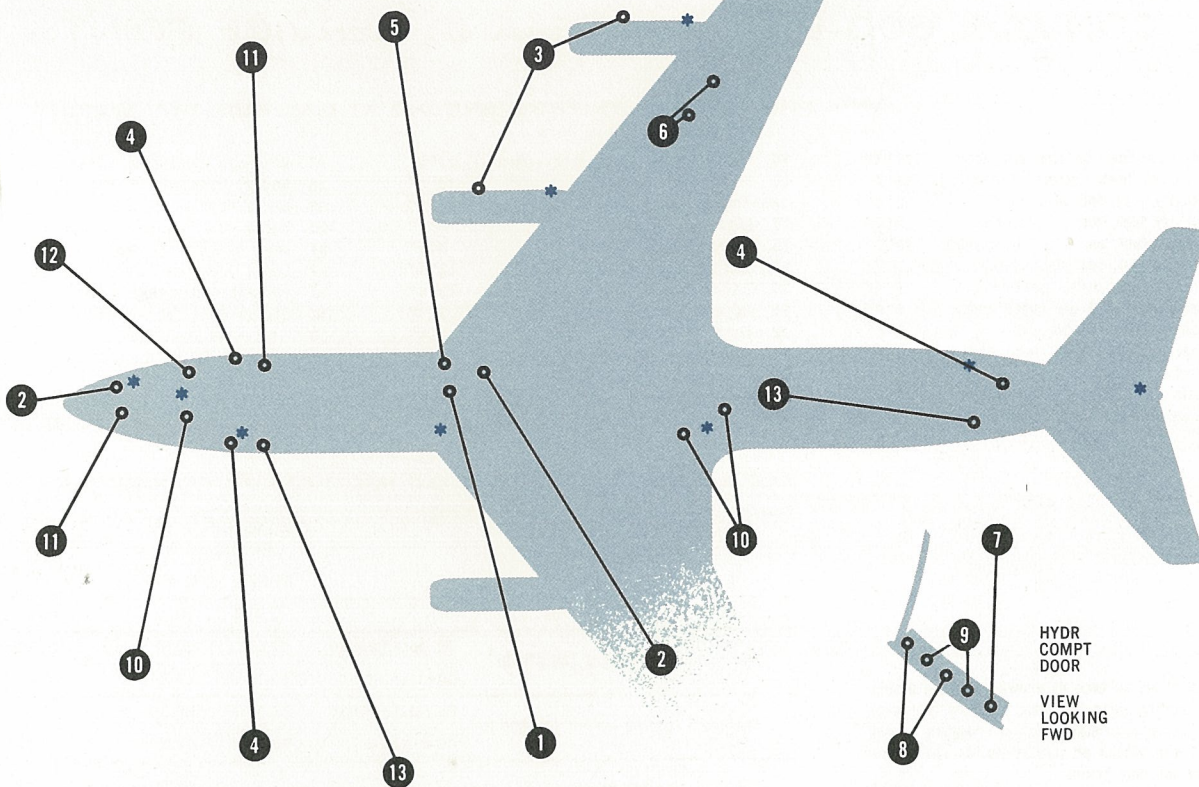


Table of Fluids

FLUID	SPECIFICATION	COLOR	UNIT CAPACITY		QUANTITY PER AIRPLANE FOR COMPLETE SERVICING	
			880	600	880	600
Fuel	JP-4 or kerosene		See text		10,770 gal	15,108 gal
Lubricating oil, engine	MIL-L-7808C		Engine, 4.15 gal CSD, 1.72 gal		23.48 gal	
Lubricating oil, turbo compressor	MIL-L-6085 (Esso Univis B-38, Aero Shell Fluid 12, or equivalent)				Approx 1 qt	
Lubricating oil, Freon additive	Fed. Spec. VV-L-820 (Texaco Capello AA or equivalent)		15 oz per unit		Approx 1 qt	
Freon 114	Dichlorofluoroethane		Approx 16 lb each		36 lb	
Hydraulic Systems	Skydrol 500A	Purple	Approx 11½ gal. in No. 1 and No. 2 reservoirs		Approx 45 gal in No. 1 and No. 2 systems	Approx 50 gal in No. 1 and No. 2 systems
NLG strut	MIL-H-5606A (MIL-H-6083 fluid, which is MIL-H-5606A with rust inhibitor additive, may be used in lieu of MIL-H-5606A)	Red	Approx 1 gal	Approx 1 gal	Approx 5 gal	Approx 6 gal
MLG strut			Approx 2 gal each	Approx 2½ gal each		
MLG truck positioner			Approx ¼ pt each		Approx ½ pt	
NLG liquid spring			Approx 1 pt	None	Approx 1 pt	None
Water	Potable		50 gal M-R* 75 gal L-R*	50 gal	50 gal	50 gal
Engine fire extinguisher	Bromotrifluoromethane		6½ lb each		26 lb	

CONVAIR 600-DIMENSIONS AND SERVICE POINTS

APPROXIMATE HEIGHTS FROM GROUND AT MAXIMUM TAXI WEIGHT

1 Pressure fuel, bottom wing inbd	11' 1"	14 Ramp electric receptacle — fwd	11' 8"	27 Passenger door floor — fwd	9' 7"
2 Pressure fuel, bottom wing outbd	11' 3"	15 Ramp electric receptacle — aft	13' 4"	28 Service door floor — fwd	9' 9"
3 Gravity fuel, top wing inbd	10' 5"	16 Electric equip doors — LH & RH	6' 3"	29 Cargo floor — fwd door	5' 8"
4 Gravity fuel, top wing outbd	12' 8"	17 Electronic door	4' 8"	30 Cargo floor — aft large door	6' 7"
5 Gravity fuel, anti-shock body inbd	10' 6"	18 Hydraulic service points	6' 8"	31 Wing tip trailing edge	12' 8"
6 Gravity fuel, anti-shock body outbd	11' 2"	19 Tail cone door — fwd	11' 4"	32 Cargo floor — aft small door	7' 1"
7 Gravity fuel, center section	9' 4"	20 Tail cone door — aft	13' 4"	33 Passenger door floor — aft	11' 3"
8 Engine and CSD oil, outbd pod	8' 9"	21 Nose wheel well top door	8' 9"	34 Service door floor — aft	11' 3"
9 Lowest point, outbd pod	3' 6"	22 Water filler inlet	5' 4"	35 Fin tip trailing edge	39' 2"
10 Engine and CSD oil, inbd pod	8' 3"	23 Lavatory service fwd	7' 6"	36 Stabilizer tip trailing edge	17' 11"
11 Lowest point, inbd pod	2' 9"	24 Lavatory service — aft	9' 2"	37 Nose jack point	6' 0"
12 Main electric power receptacle	5' 5"	25 Conditioned air inlet	6' 2"	38 Wing jack points	8' 9"
13 Nose electric power receptacle	6' 3"	26 Low-pressure air inlet	6' 3"	39 Lowest point fuselage (Sta 907)	5' 0"

TABLE OF HEIGHTS OF WL 0.0 FROM STATIC GROUND LINE

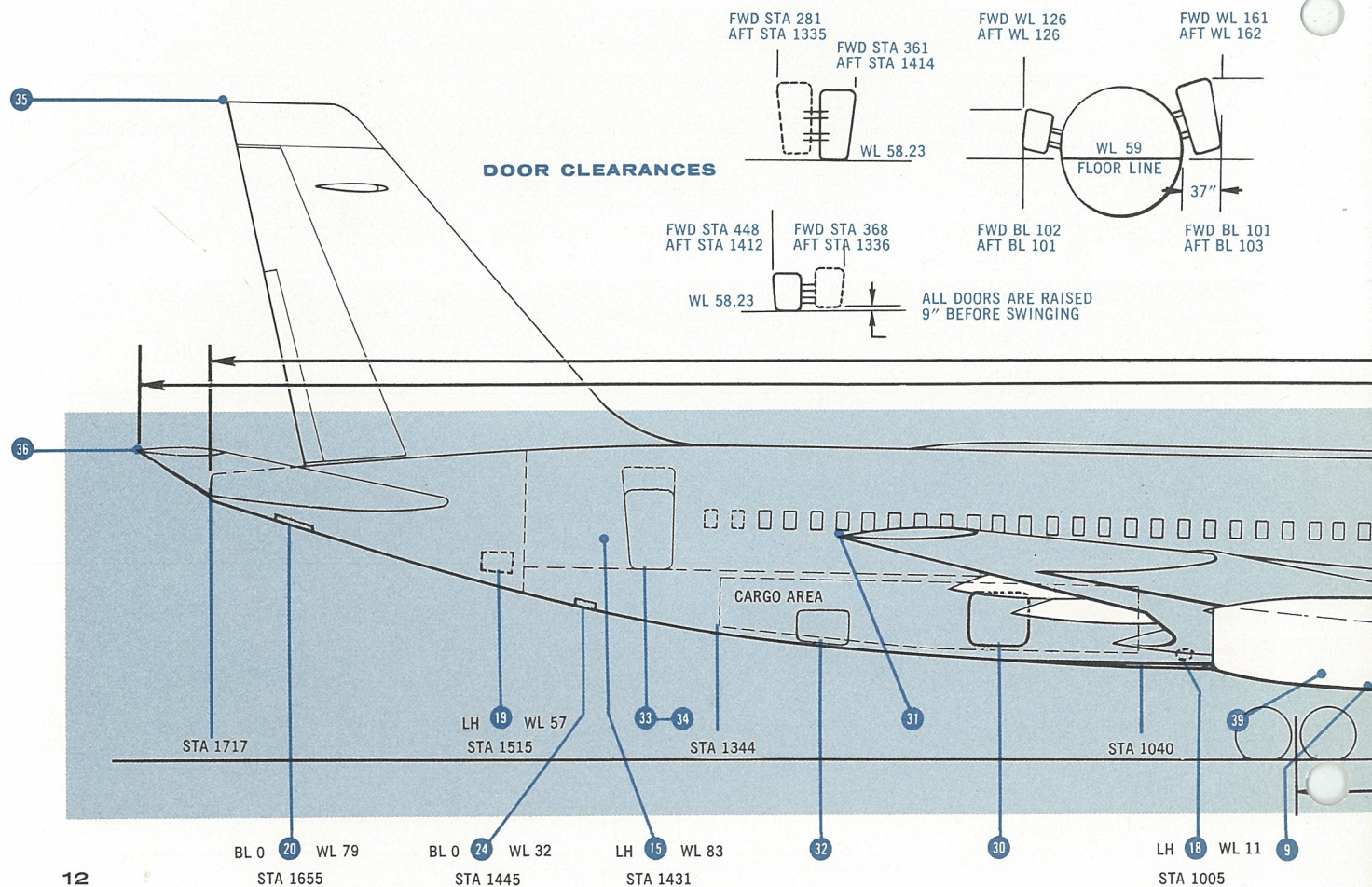
CONDITION	FROM WL 0.0 TO GROUND LINE		ANGLE OF WL WITH GROUND LINE
	AT NLG	AT MLG	
Static position (theoretical)	52.45"	67.8"	1° 16'
Maximum ramp weight 239,000 lb	CG most forward	52.6"	1° 17'
	CG most aft	55.1"	1° 4'
Maximum landing weight 180,000 lb	CG most forward	54.2"	1° 17'
	CG most aft	62.5"	0° 34'
Empty weight 115,000 lb	CG most forward	57.5"	1° 18'
	CG most aft	62.5"	0° 51'

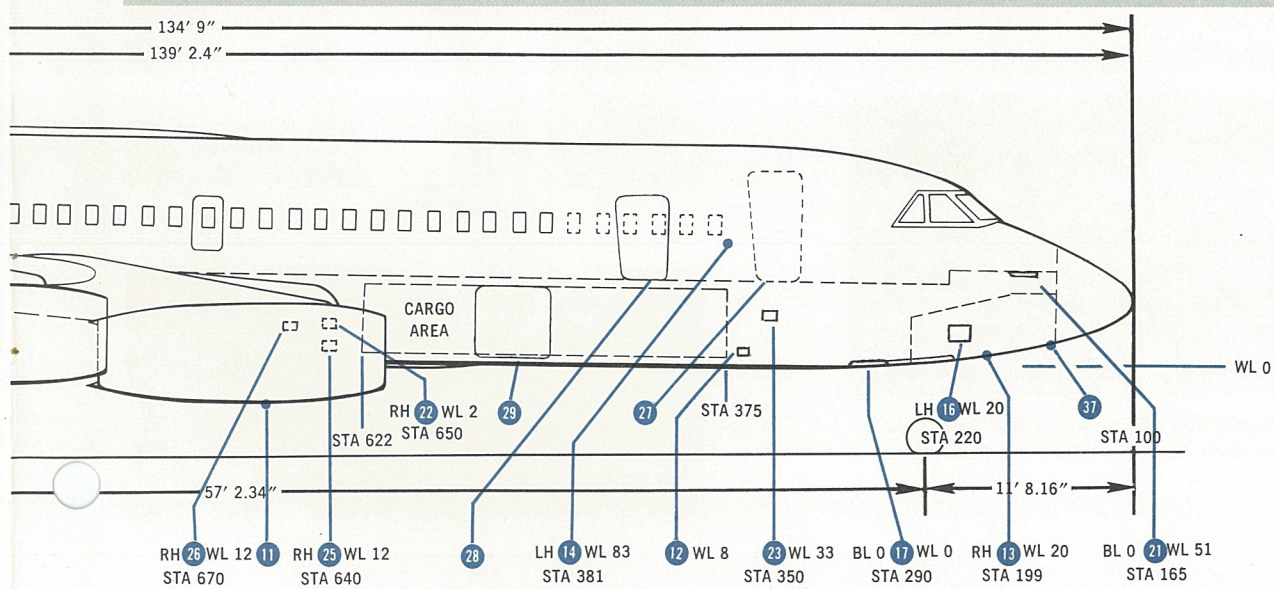
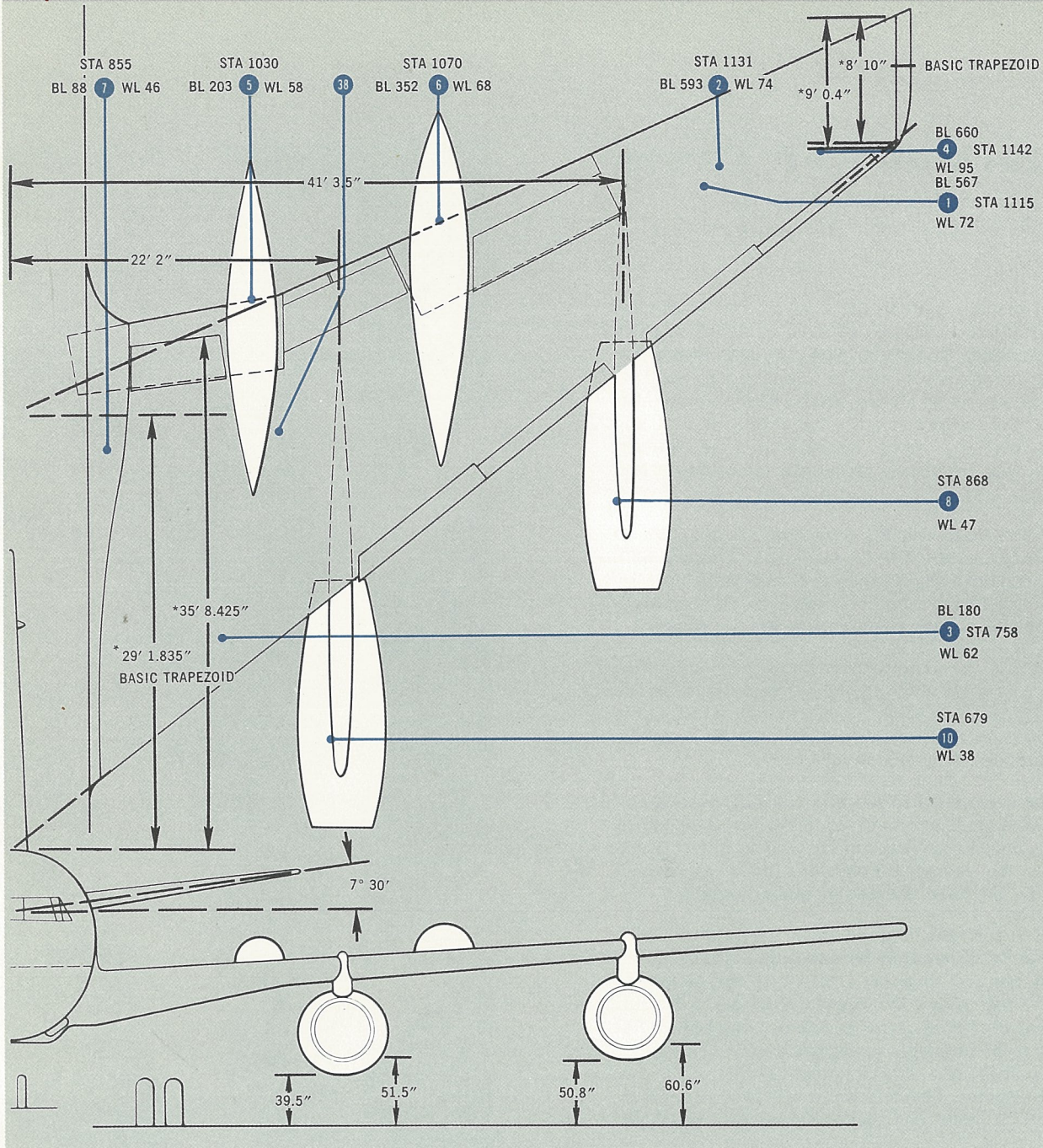
NOTES

Heights given on face of drawing are jig dimensions, landing gear in static position (theoretical). For approximate actual heights above ground, see tables of service points and waterlines at landing gears.

*Dimensions thus referenced are in manufacturing chord plane (7° incidence, 4° dihedral).

DOOR CLEARANCES





Fuel Jettison Tests

... qualitative results
were well above minimum requirements ...

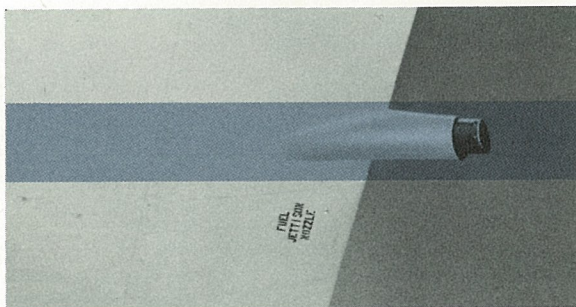
Fuel management on the Convair 880 is handled by four separate systems: *Fueling*, or defueling when it is necessary to remove fuel for tank inspection; *Engine Supply*, which permits directing the fuel from any tank to any or all engines; *Venting*, which takes care of the expansion and contraction of fuel and vapors resulting from temperature and altitude changes; and *Jettisoning*, sometimes referred to as fuel dumping.

The first three systems were checked out prior to and during the initial flight tests of the Convair 880. The fuel jettisoning system test was completed recently. Qualitative results obtained on this test were well above minimum requirements for the system.

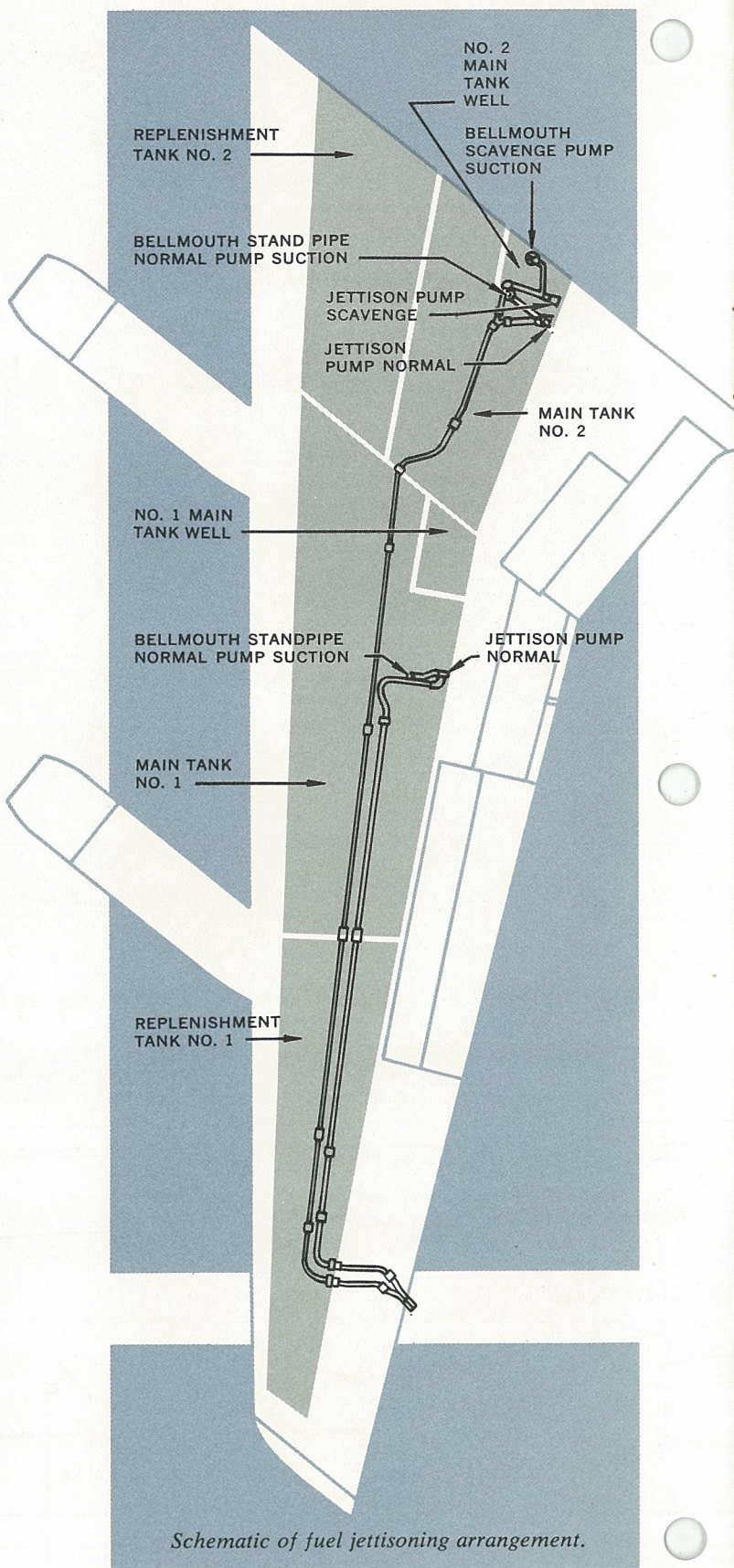
Basically, the requirement for a fuel jettisoning system is brought about by the difference between the airplane maximum takeoff gross weight, which is the design weight for the airplane fully loaded, and the maximum design landing weight.

In the event the airplane takes off fully loaded and the pilot finds it necessary to make an unscheduled landing, fuel jettisoning can be used to dump excess fuel into the atmosphere and thus reduce the overall weight to, or below, the design landing weight.

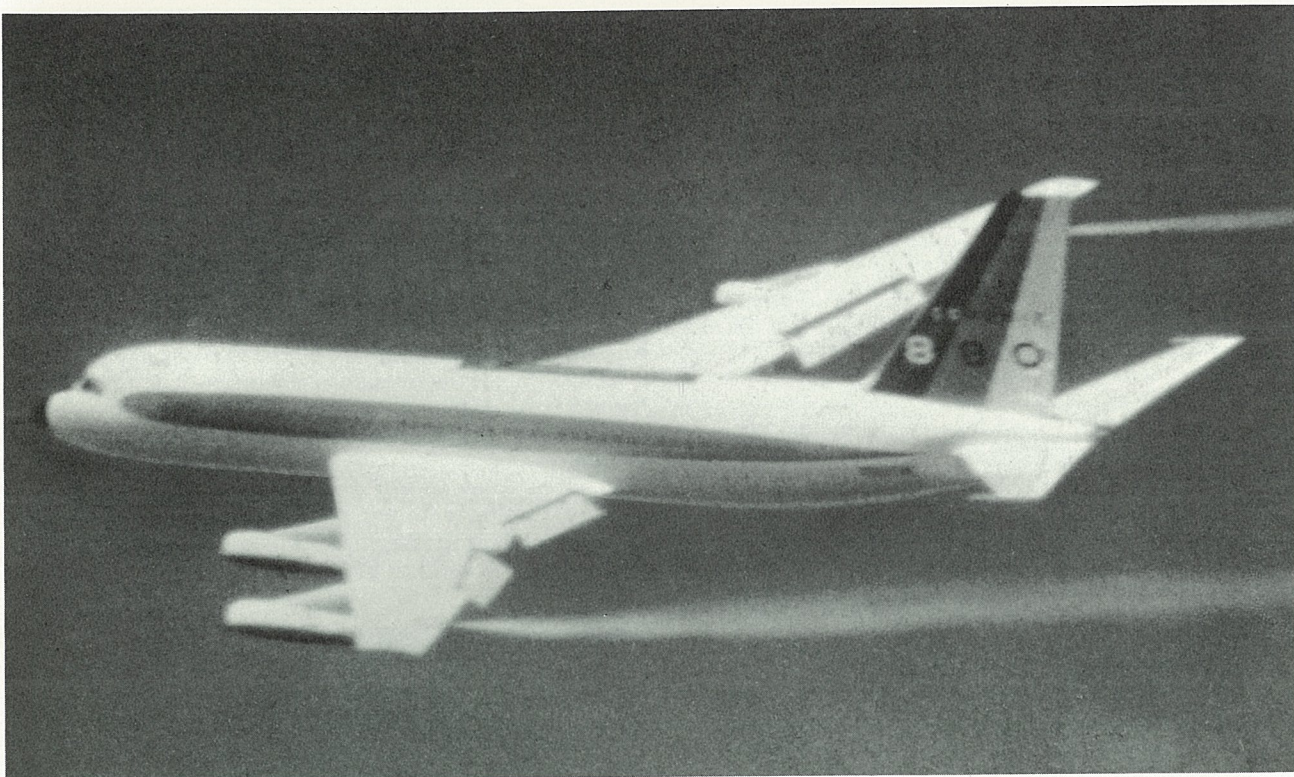
Civil Air Regulations establish the rate at which fuel is to be disposed of by jettisoning. This requirement is not less than one percent of the maximum takeoff gross weight per minute. For the "880" this would be 1845 pounds per minute or a total of 51,700 pounds to be unloaded in approximately 28 minutes. The first flight test showed a considerably better rate of fuel disposal. This test was conducted at approximately 170 knots indicated airspeed in level flight,



Fuel jettison nozzles are permanently fixed and are streamlined to provide a clean configuration.



Schematic of fuel jettisoning arrangement.



Enlarged frame taken from motion picture of actual fuel jettisoning during tests. White "plumes" are fuel being jettisoned. Note that ejection pattern exhibits no indication of impingement on any portion of airplane.

with the wing flaps at 50 degrees deflection, and landing gear retracted.

Fuel was jettisoned from all four tanks, simultaneously, for a period of 6.25 minutes. The fuel jettisoning was switched to the inboard tanks only, for an additional 4.0 minutes. During the test, the fuel, jettisoned from the inboard tanks, was 13,000 pounds and from the outboard tanks, 7800 pounds.

Based on an average jettison rate of 630 pounds per minute per tank, with all four tanks dumping simultaneously, the combined rate would be 2520 pounds per minute, as compared with the CAR requirement of not less than 1 percent of maximum airplane takeoff weight or 1845 pounds per minute. The time required to reduce the airplane to maximum allowable landing weight would be 20.5 minutes as compared to 28 minutes. These are direct jettisoning results only, and do not include engine fuel consumption during this time. Engine fuel consumption during the jettisoning would reduce the time below 20.5 minutes.

Effective fuel jettisoning is attributed to a simple and efficient system. Electrical switches, located in the flight compartment on the flight engineer's control panel, energize solenoids which release hydraulic power to hydraulic motors that drive the jettison pumps.

Actual pumping of fuel overboard is accomplished by hydraulic power, rather than by electrical power or other means which would introduce a potential fire hazard. Pumping lines are contained largely within the fuel tanks. They are designed to be filled with fuel, and are drained automatically into the tanks. The fuel they contain thus becomes available for normal engine use.

A standby arrangement in the jettisoning system assures that a minimum of 7730 pounds of fuel will remain in the inboard tanks, if fuel is jettisoned, so that engine fuel requirements will be available during the emergency period. Scavenge-jettison pumps, however, can be used to completely empty the inboard tanks. They are used to remove fuel from proximity to the passenger cabin as a safety factor if an emergency landing is necessary.

Actual nozzles for jettisoning the extra fuel from the airplane are located just aft of the outboard ends of the outer wing tanks. They extend aft of the wing trailing edge and are permanently fixed and streamlined, eliminating any necessity for mechanical and drive equipment, as would be required with retracting nozzles.

The recent tests displayed good dispersal rates and patterns with no indications of fuel impingement. The fuel was dumped overboard rapidly and cleanly.

Convair 880 Passes Tests with Flying Colors

The Convair 880 jet transport can fly 615 miles an hour in level flight — faster than any other commercial passenger plane in the world! Six months of intensive flight testing indicate that the “880” meets or exceeds all of its other performance estimates, including the predicted short takeoff and landing runway lengths for which this medium-range jet airliner was specifically designed.

The “880” attains its level-flight 615-miles-an-hour true airspeed with maximum cruise thrust from its four powerful General Electric CJ805-3 turbojet engines. The reliability and performance of these engines and of the airplane itself have been outstanding.

Engineering estimates of the “880’s” range and fuel operating economy have also been confirmed by data accumulated during 250 hours aloft on 130 flights (as of August 10) with the first two test aircraft. This is true for both the 3,450-statute-mile maximum range, when the “880” is flown for best economy, and also for lesser, medium ranges flown at higher speeds. In every instance, fuel consumption by the four CJ805-3 engines equals or betters the estimates at each of several altitudes for which flight data have been taken.

The certified landing field length for the “880” with full first-class payload was estimated at 5,350 feet when the design was established three years ago. Landing tests to date have shown this distance may be significantly shortened. Landing roll was tested by using brakes only to slow the airplane — that is, without applying engine power to the thrust reversers with which the airplane is equipped. The use of the General Electric thrust reversers, already proved out in extensive taxi tests, provide an additional safety margin.

The runway length required for an “880” takeoff has been demonstrated to be within the estimates made to airline customers. This includes a 5,450-foot runway requirement for takeoff at sea level standard conditions on a typical 1,000-mile medium-range trip.

Aircraft manufacturers traditionally establish performance estimates of a demanding nature to serve as design goals that will challenge design engineers,

fabricators, and suppliers to their utmost. Performance guarantees, which are assumed by the manufacturer as contractual obligations when an airline orders the new equipment, often before production has begun, contain tolerances acceptable to both manufacturer and airline. It is rare that a new aircraft can meet or exceed the performance estimates conceived at the drawing board stage, but this is exactly what the “880” has done. These achievements by the Convair 880 are a tribute to the many skilled engineers who spent thousands of manhours on the design of the nation’s fastest, most versatile, and most advanced luxury jet airliner.

The first Convair 880 made its maiden flight on January 27, and a second ship joined the flight test program in March. Another complete airplane has undergone six months of proof-load tests at the

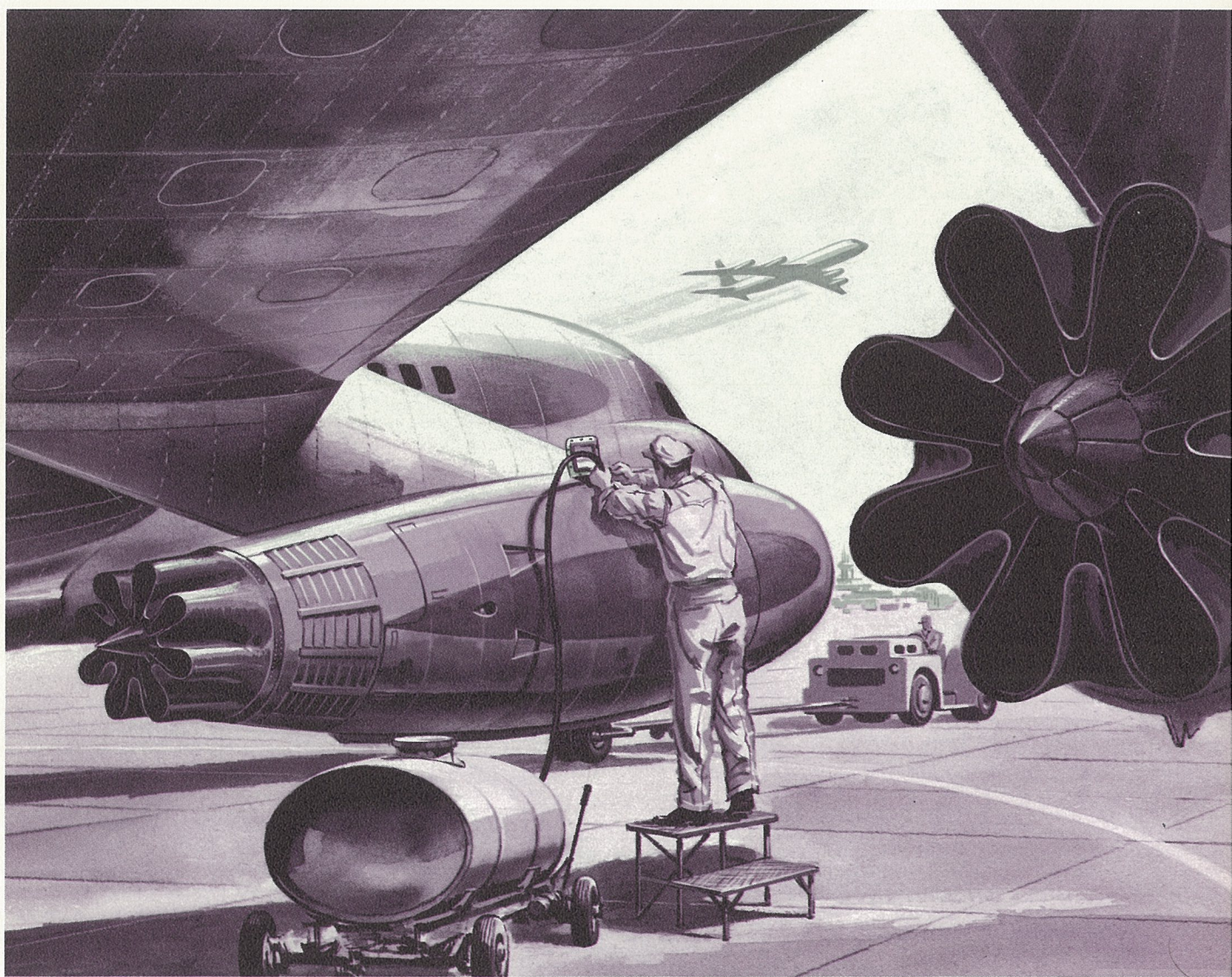


Convair San Diego Structural Test Laboratory. A third flight test airplane joined the test program on August 9. Federal Aviation Agency certification flights are to begin this month.

While the “880” was designed and built to operate from most present-day airports, the large fuel storage capacity of its swept wing and the economy of its General Electric engines have given the airplane an additional capability of flying transcontinental as well as medium-range routes, making premium jet service available to smaller cities as well as to metropolitan centers.

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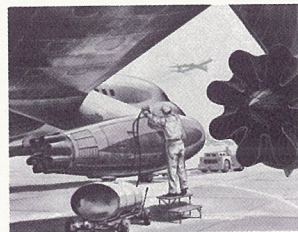
Convair Traveler



In this Issue: Convair 880 Engine Oil System

VOLUME XI NUMBER 6 OCTOBER 1959

Convair *Traveler*



In this Issue: Convair 880 Engine Oil System

OUR COVER

Artist Jack Davis graphically portrays the ease with which maintenance personnel can service Convair 880 engines. In this case, the inboard engine oil tank is being filled, using ground level equipment.

Convair *Traveler*

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Convair 880

Engine Oil System

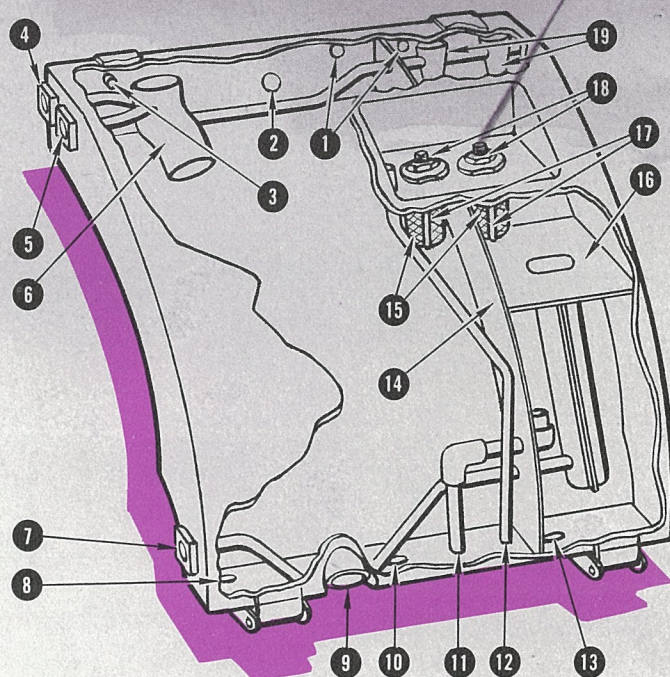


The oil system on the Convair 880 is a pressurized, recirculating system that has two important functions. Its first and primary function is to lubricate the bearings and gears on the engines; its secondary function is to cool them. An oil system reservoir, mounted on each engine, is separated into two compartments. (See cutaway diagram of oil tank.) One compartment supplies oil for the engine, the other compartment contains oil for the hydraulic section of the a-c generator constant speed drive and also for the engine thrust reverser system. (A future issue of the Convair Traveler will cover the engine thrust reverser system.)

The two compartments of the oil reservoir are connected by an external pressure equalizing line ported to the expansion spaces provided in each compartment. The engine oil compartment holds 4.15 gallons of oil with an expansion space of 1.26 gallons. The CSD and thrust reverser compartment holds 1.72 gallons of oil, with an expansion space of 0.50 gallon. With the tank filled, the engine has a normal operating capability of 13.6 hours. At the end of that time the engine compartment should contain approximately 1.10 gallons and the CSD compartment 1.53 gallons. This reserve is sufficient to permit the engine to be inclined 30° up or down, or rolled into a 20° left or right bank without uncovering the oil outlets.

Hand-fill or gravity servicing ports for each compartment are located near the top of the tanks. A dipstick that forms an integral part of each gravity fill cap is provided, and the gravity fill ports are recessed into the tank so that the caps protrude only slightly. A de-aerator is incorporated in the scavenge return line of each compartment to separate the entrained air from the oil prior to the starting of oil recirculation.

The engine oil supply system is divided into three subsystems: supply oil, scavenge oil, and sump pres-



Engine Oil Tank Cutaway

- | | |
|------------------------------|----------------------------------|
| 1 PRESSURE EQUALIZER PORTS | 11 CSD SUPPLY |
| 2 VENT OUTLET | 12 SCUPPER DRAIN |
| 3 SUMP VENT INLET | 13 CSD COMPARTMENT DRAIN |
| 4 CSD RETURN | 14 COMPARTMENT DIVIDING BULKHEAD |
| 5 ENGINE SCAVENGE RETURN | 15 FILTER SCREENS |
| 6 DE-AERATOR | 16 CSD ANTI-G BAFFLES |
| 7 THRUST REVERSER SUPPLY | 17 DIPSTICKS |
| 8 ENGINE COMPARTMENT DRAIN | 18 FILL PORTS |
| 9 OIL LEVEL TRANSMITTER PORT | 19 DE-AERATOR |
| 10 ENGINE SUPPLY | |

surizing. (See lubrication system schematic.) Leaving its reservoir, the supply oil flows to an engine-driven supply pump which increases the pressure from 20 psig to 65 psig (depending upon engine speed) and discharges the oil through an anti-leak check valve to the supply oil filter. Filtered oil is then directed to a T-fitting which divides the flow to supply the front gearbox and the No. 1 engine bearing, the transfer gearbox (front accessory case), and the horizontal drive shaft damper bearing.

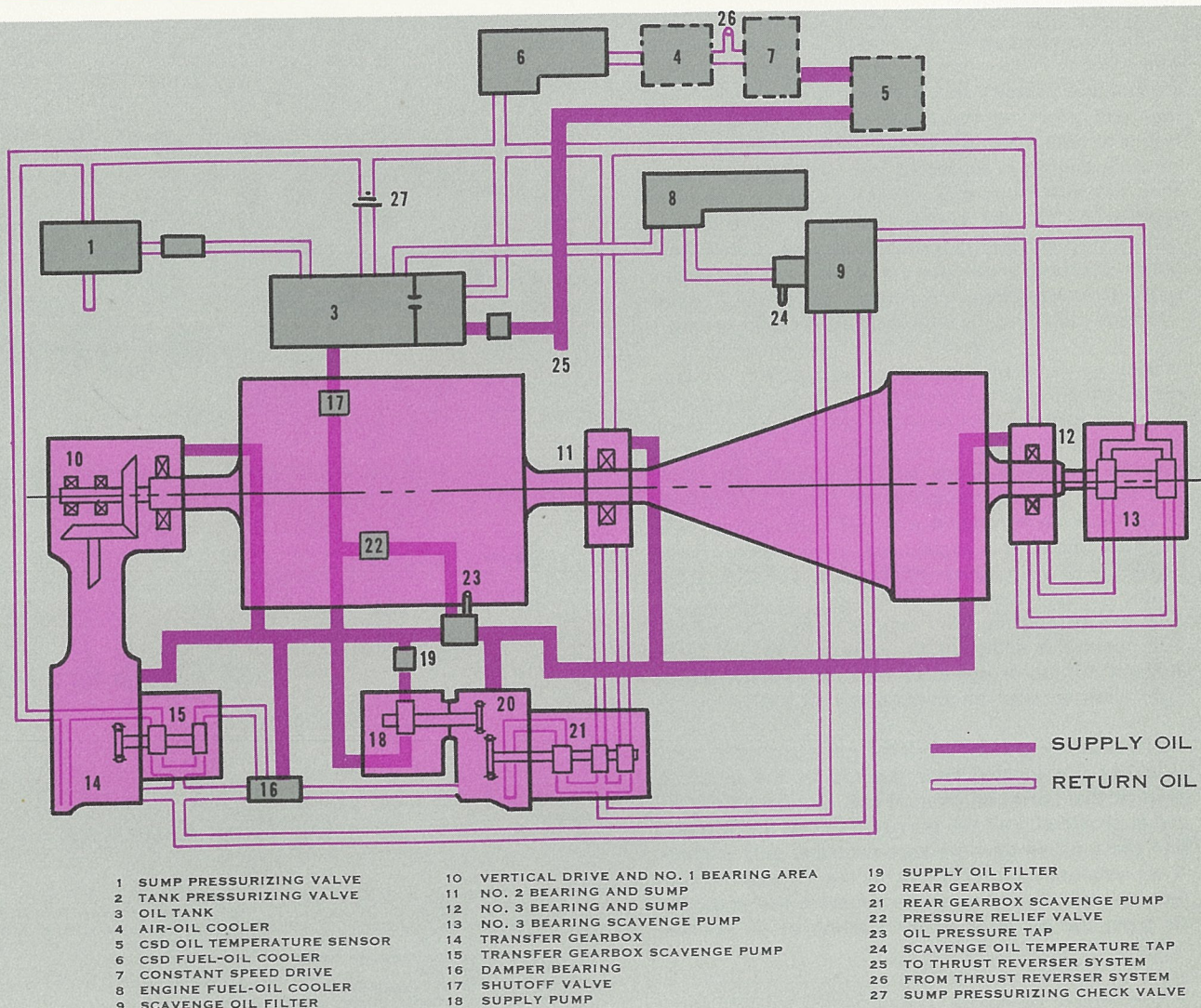
Oil is routed to five oil jets in the front gearbox and No. 1 bearing area through the No. 5 compressor front frame strut. Seven oil jets distribute the oil in the transfer gearbox and one additional jet supplies oil to the horizontal shaft damper bearing. The T-fitting line also supplies oil to the rear gearbox where four jets distribute the oil. A line through the No. 5 strut of the compressor rear frame carries the oil to the No. 2 bearing area where four jets distribute the oil. Oil to lubricate the No. 3 bearing is routed through

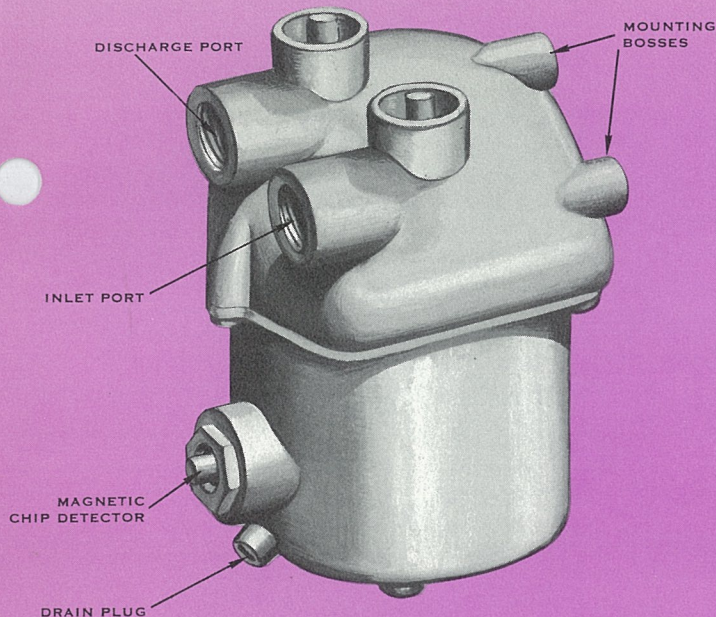
the No. 3 strut of the rear turbine frame where three jets distribute the oil over the No. 3 bearing.

The oil supply pump is a single element pump with a rated flow of 9.5 gpm (60 psi) at 100% engine speed, based on a pump inlet pressure of 25 to 30 in. Hg (absolute) and an oil temperature of 300°F. After leaving the pump, oil enters a filter through a single inlet port, passes through the cartridge into the inner chamber and then flows out the discharge port. If the filter becomes clogged, oil is bypassed across the filter through a pressure relief valve to the discharge port. A differential pressure of 14 to 16 psi across the filter is required to unseat the relief valve. A port is provided to drain the filter prior to removal for cleaning or inspection.

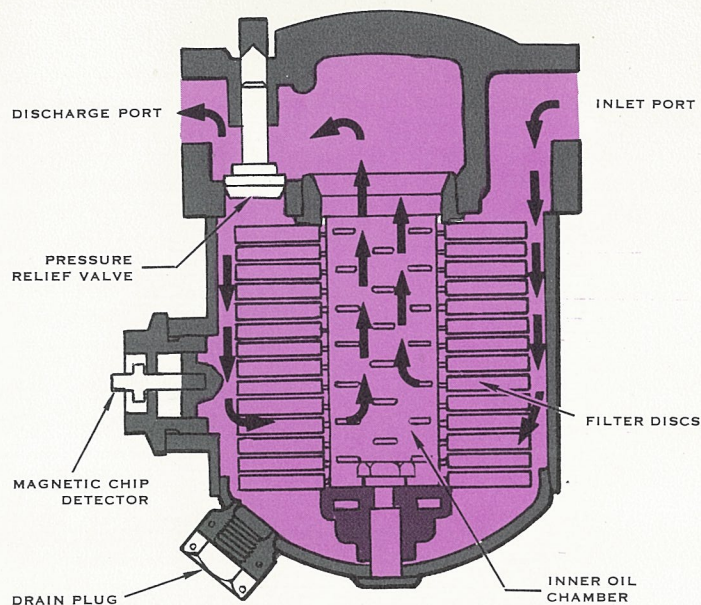
The body of the filter contains a magnetic chip detector adjacent to and above the drain plug. The filter element is comprised of a stack of "pancake"

Lubrication System Schematic





Oil Filter



Oil Filter Schematic

elements capable of filtering out particles exceeding 46 microns in size. With oil at 150°F and a flow of 15 gpm, the pressure drop across a clean filter is approximately 6 psi; estimated maximum pressure drop across a clogged filter is 23 psi. In addition to the magnetic chip detector, an electrical chip detection pickup is provided in the filter. By attaching a milliammeter to this pickup and completing the circuit, the quantity of ferrous deposits in the filter sump can be determined.

Oil in the bearing sumps, damper bearings, and accessory cases is scavenged, filtered, cooled, and returned to the engine section of the oil tank, by means of three scavenge pumps where it is de-aerated. Capacity of the scavenge subsystem is approximately two and one-half times the actual amount of oil supplied to any one area.

During all flight attitudes, scavenge oil from the No. 1 bearing sump and the front gearbox drains through the No. 5 compressor front frame strut to the transfer gearbox and is returned to the oil tank by one element of the transfer gearbox scavenge pump. The scavenged oil then flows from the horizontal transfer shaft damper bearing to the second element of the transfer gearbox scavenge pump. Both elements discharge to the scavenge filter.

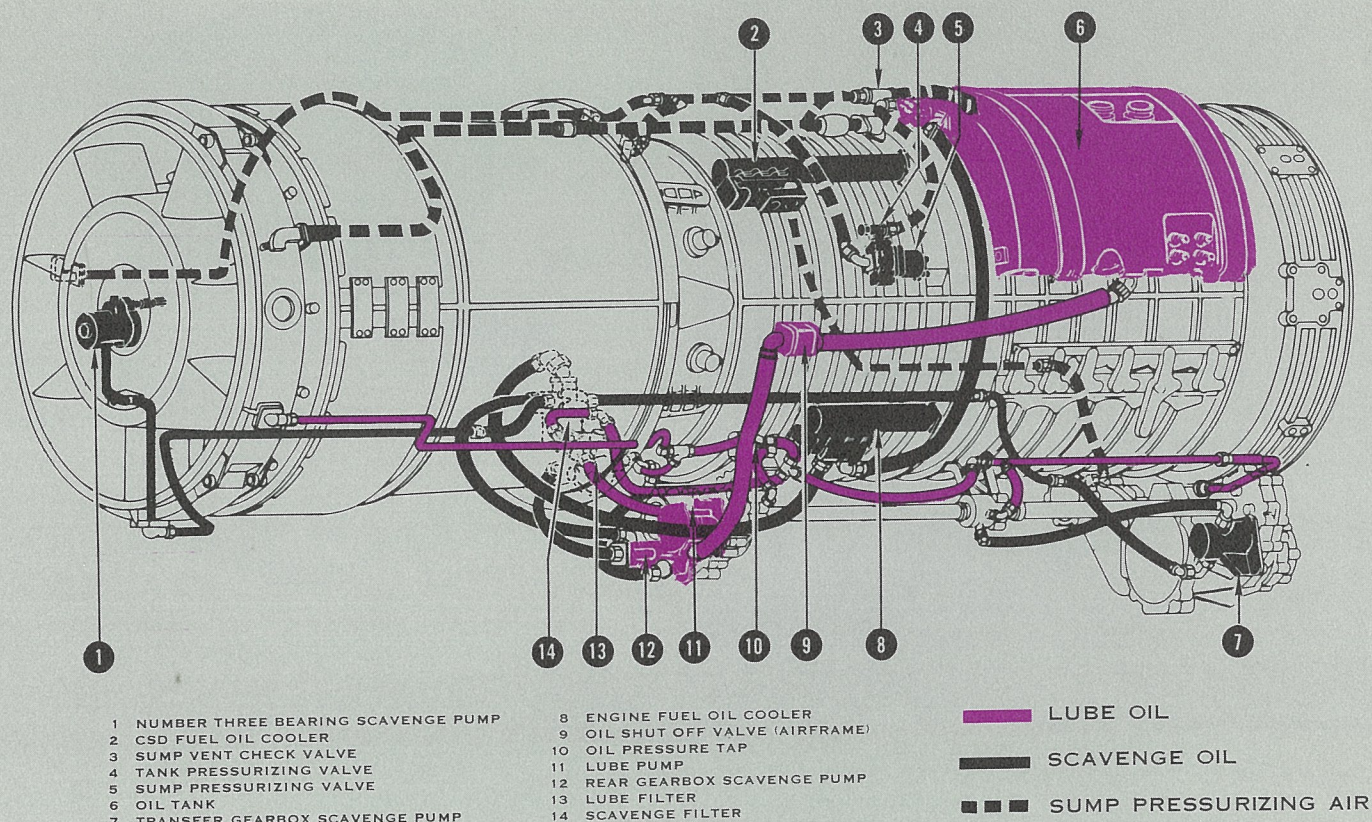
The rear gear box scavenge pump is a three-element type with each element inlet independent of the other. One element scavenges oil from the bearings and gears in the rear gear box; another element scavenges oil which flows through the No. 6 strut of the compressor frame from the "dive" sump of the No. 2 (thrust) bearing. Oil from the "climb" sump of the No. 2 bearing flows through the No. 5 strut of the compressor rear frame and into the third element of

the scavenge pump and, as in the other two elements, the discharge oil is routed to the scavenge filter. Another pump, a two-element, shaft-driven type, is used to scavenge the "climb" and "dive" sumps of the No. 3 bearing. The scavenged oil is pumped through the No. 5 turbine frame strut and routed to the scavenge oil filter.

After the engine oil passes through the scavenge oil filter, it is directed into the engine fuel/oil cooler. Here the oil is cooled by the engine fuel which flows through the core of the cooler. At oil inlet temperatures below 100°F, a pressure relief valve opens and bypasses the oil around the cooler core. A fuel temperature sensor opens the oil bypass valve when fuel temperatures reach 241°F, because the fuel cannot safely absorb additional heat from the scavenge oil. Then the scavenge oil is returned from the cooler to the engine compartment of the oil tank, where entrained air is separated from the oil, rendering it ready for re-use.

Ordinarily, oil flows through the inlet port and into and out of the engine fuel/oil cooler. If, however, the temperature of the scavenge oil falls below 38°C (100°F), the pressure drop across the oil bypass valve will then be sufficient to compress the oil bypass valve spring and force the valve from its seat. A portion of the oil then bypasses the cooler core and flows through the bypass to the outlet. As the temperature of the oil increases, the pressure drop across the valve decreases and the oil bypass valve closes, forcing all the oil through the cooler core, after which it returns to the engine compartment of the oil tank.

Linked to the fuel/oil cooler shutoff valve is a fuel temperature sensor. When the fuel temperature reaches 117°C (241°F), a thermostatic element of the



Lubrication System in Relation to CJ805-3 Engine

sensor expands, tending to close the shutoff valve. The resulting increased pressure differential across the oil portion of the cooler opens the oil bypass valve and the oil flows through the bypass port of the oil outlet. Enough oil is bypassed to prevent the discharge fuel temperature from exceeding 124°C (255°F). The maximum pressure drop across the fuel portion of the cooler is 50 psi at a flow of 15,000 gph.

The sump pressurizing subsystem regulates the head of air pressure on oil in the tank, oil in the accessory case gearboxes, and oil in the bearing sumps. This assures proper operation of the supply and scavenge pumps under varying altitudes and operating conditions. Compressor air, bleeding across the bearing seals and into the bearing sumps, pressurizes the bearing sumps and the three gearboxes. These areas are manifolded together and vented through a check valve into the oil tank and to the tank pressurizing valve. An orifice in the tank pressurizing valve bleeds off any excess air pressure above that which is required to establish a system pressure of 3 to 4 psi above ambient pressure. Excess air is bled overboard through a vent in the valve where a check valve within the tank pressurizing valve is used as a relief valve for momentary pressure changes.

A check valve within a valve is operated by a bellows, vented to ambient pressure. The bellows is designed to hold the vent open at an altitude below

20,000 feet. At 20,000 feet, the valve begins to regulate sump pressure, and at 28,000 feet, the valve attains full regulation. At 28,000 feet and above, the tank pressurizing valve will establish a higher head of pressure in the oil tank and sumps (approximately 5 to 7 psi above ambient pressure). Since the CSD and engine oil tank compartments have a common vent, they will both be pressurized in a like manner.

Under some conditions, air must be supplied from an outside source. Below 20,000 feet, air is drawn in through the open bellows-operated check valve in the sump pressurizing valve and discharged into the sump areas through the check valve in the sump pressurizing valve. The air is scavenged with the oil and routed to the oil tank where the entrained air is separated from the oil and the excess air is vented either to ambient or back into the sump areas. The same process applies if air is needed to pressurize the sumps at altitudes above 28,000 feet except that the bellows-operated check valve is now seated and the pressurizing air must enter the system through the vacuum relief valve and the check valve of the sump pressurizing valve. An additional check valve allows excess sump pressurizing air to bleed into the oil tank but restricts flow in the opposite direction. At certain engine operating conditions, the sump pressure decays much faster than tank pressure. This check valve prevents the higher pressure in the oil tank from forcing oil backwards across the bearing seals.

Aspects of the lubrication system of particular interest from a design limit standpoint are listed in the lubrication system limits table. Two limits are shown — normal and extreme. *Normal* limits define the range encountered during normal operation; *extreme* limits define a range that may be encountered less than 5% of the operating time.

LUBRICATION SYSTEM LIMITS

1. Lube Oil Temperature into Engine as High as:
 Normal Limits 100° to 250°F (38° to 122°C)
 Extreme Limits —40° to 300°F (—40° to 149°C)
2. Lube Oil Temperature out of Engine:
 Normal Limits 150° to 300°F (66° to 148°C)
 Extreme Limits —40° to 350°F (—40° to 177°C)
3. Lube Oil Pressure:
 Normal Limits 12 psig minimum at Idle rpm
 Normal Limits 35 to 60 psig at Max rpm with oil in at 135°F
 Extreme Limits 30 to 500 psig at 100% rpm (gauge limit 200 psi)

It is interesting to note that immediately following engine starts, after prolonged soak periods in cold weather, supply oil pressure can range as high as 500 psig before the oil begins to warm up. The pressure indicator on the flight engineer's panel, however, reads only as high as 200 psig, which is the gage limit. The oil pressure tap, located at "5 o'clock" on the compressor rear casing, contains two calibrated orifices which work with a pressure relief valve to protect the oil pressure transducer from extreme pressure surges.

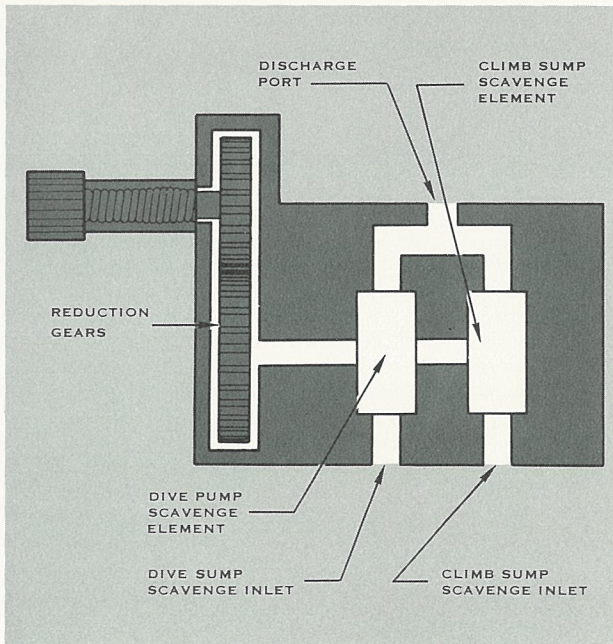
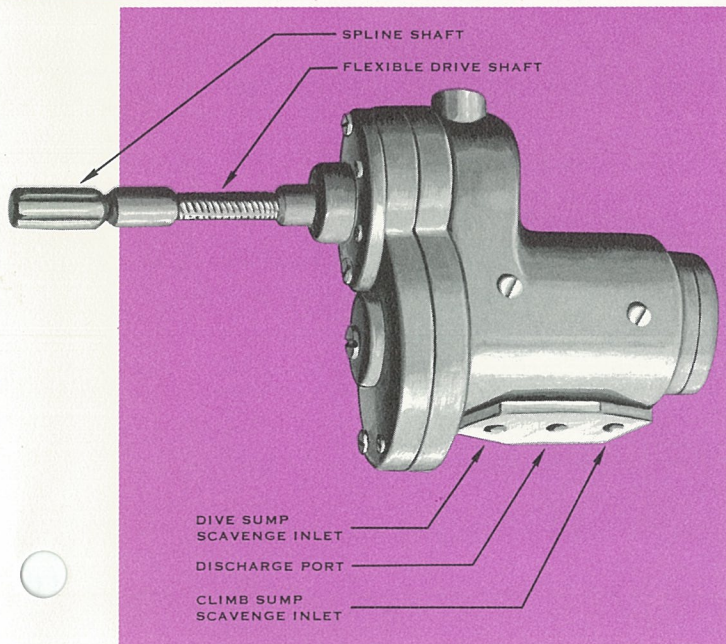
There is an engine oil pressure indicating system which consists of a synchro type oil pressure transmitter and synchronous indicator. The transmitter is mounted at the engine rear gear box oil pressure port, and the indicator is installed on the flight engineer's instrument panel. The oil pressure, entering directly

into the transmitter through an orifice, actuates a differential pressure sensing unit used to position a synchro-motor assembly. This assembly, in turn, remotely positions a pointer on the indicator. The system is duplicated for each engine and is operated by power from the 26-volt, single-phase, 400-cycle, a-c essential bus.

An oil-low-pressure warning system is incorporated in conjunction with the oil pressure indicating system. It consists of an oil pressure warning light on the pilot's master warning panel and a pressure switch, line-mounted, adjacent to the engine rear gear box. The pressure switch is set to illuminate the warning light when the pressure drops to 9 ± 1 psig and to extinguish it when the pressure increases to 12 psig or above. Mounted on the flight engineer's panel are four dial indicators that reflect the oil temperature of each engine. Each oil temperature indicating system consists of a temperature bulb, located in the return line between the oil scavenge filter and oil cooler, and the indicator. The bulb acts as part of a bridge circuit in the indicator, causing an unbalanced condition in the circuit which in turn is reflected in degrees of temperature on the indicator dial.

There are four oil quantity indicating systems, one for each engine. They consist of capacitance-type electronic bridge circuits that indicate the quantity of oil in gallons in each engine tank. These are in addition to the direct-reading dipsticks described earlier. Each of the electronic indicating systems use 115-volt, 400-cycle, a-c power from the No. 3 essential a-c bus. A capacitor probe is installed in each engine oil tank and an amplifier unit is installed in the electronic compartment with the quantity reading gages mounted on the flight engineer's panel.

Scavenge Pump



The advent of turbojet engines and high performance aircraft introduced an entirely new set of fuel requirements. Fuels for piston engines had reached a high state of development and performance, but their adaptation to jet engines was found to be unsuitable in many ways. Although aviation gasolines can, in some cases, be used in jet aircraft in an emergency, their physical and thermal properties are such that unless fuel systems and engines are designed for such fuels, damage could result.

Out of this new type of airplane and its new fuel specifications grew an equally new set of fuel system requirements, the Convair 880 and 600 airplanes representing an advanced achievement of these requirements. Convair engineers designed the 880/600 fuel tanks, fuel sealants, and fuel system components, structurally and from a fuel-resistant standpoint, to use JP-4 type fuel, aviation gasoline, and kerosene type fuel, of aromatic content from 0 to 30 percent. The fuel tanks and components were also designed to operate at any altitude up to 45,000 feet at an ambient temperature of -80°F , with provisions incorporated to prevent thrust loss, due to freezing of moisture or other materials in the fuel. At the other extreme, either airplane can operate satisfactorily with initial fuel temperatures up to $+130^{\circ}\text{F}$. Table I shows the specifications of aircraft fuels.

Specifications of jet engine fuels are based on availability, performance, and handling. The first turbojet aircraft were of a military nature and used a kerosene type fuel designated JP-1. It was quickly noted that great numbers of jet aircraft operating under emergency conditions would consume much more fuel than would be available from crude petroleum with existing refinery equipment. As a result, the next several years were spent in extensive development of a turbojet fuel specification that was satisfactory from a performance as well as from an availability standpoint. This fuel

Jet Propulsion Fuels

specification development was gradual and paralleled engine development and consequent changes in fuel performance requirements.

The step-by-step development of the current jet fuels is an example of the influence of fuel and engine research on specification requirements. These requirements were largely dictated by the desire to establish a military fuel of maximum availability, but a few of the limits on certain properties were based upon research data and operational experience that had been obtained at that time.

Although the original proposal for JP-3 fuel was made in January 1947, it was not until December of the same year that the first specification (AN-F-58) was established for JP-3 jet fuel. Some of the restrictions on the physical properties of this fuel differed from those of the original proposal, changes that resulted because some of the requirements have been shown by systematic performance research to be unnecessarily restrictive and others to be too liberal.

The second revision of the JP-3 specification was made in March 1949, at which time the permissible aromatic content was lowered to 25 percent by volume, and the bromine number (measure of unsaturated hydrocarbon content) was increased to 30. The revision also added limits to specific gravity (0.728 to 0.802) because of the importance of this factor to aircraft design.

Specification Fuel grade	SPECIFICATIONS OF AIRCRAFT FUELS							
	MIL-F-5572A		MIL-F-5616		MIL-F-5624C		ASTM (typical)	
	100/130	115/145	JP-1	JP-3	JP-4	JP-5	A	B
A.S.T.M. distillation D86-52, $^{\circ}\text{F}$								
Percentage evaporated								
10	167 (max)	167 (max)	410 (max)	—	—	400 (max)	400	—
20	—	—	—	240 (max)	290 (max)	—	—	290
40	167 (min)	167 (min)	—	—	—	—	—	—
50	221 (max)	221 (max)	—	350 (max)	370 (max)	—	450	350
90	275 (max)	275 (max)	490 (max)	470 (max)	470 (max)	—	—	470
End Point	338 (max)	338 (max)	572 (max)	—	—	550 (max)	550	—
Sum of 10- and 50-percent points	307 (min)	307 (min)	—	—	—	—	—	—
Residue, percent	1.5 (max)	1.5 (max)	1.5 (max)	1.5 (max)	1.5 (max)	1.5 (max)	1.5	1.5
Loss, percent	1.5 (max)	1.5 (max)	1.5 (max)	1.5 (max)	1.5 (max)	1.5 (max)	1.5	1.5
Freezing point, $^{\circ}\text{F}$	-76 (max)	-76 (max)	-76 (max)	-76 (max)	-76 (max)	-60 (max)	-40	-60
Reid vapor pressure, lb/sq in.	5.5 to 7.0	5.5 to 7.0	—	5.0 to 7.0	2.0 to 3.0	—	—	3.0
Aromatics, percent by volume	—	—	20.0 (max)	25.0 (max)	25.0 (max)	25.0 (max)	20.0	20.0
Total sulfur, percent by weight	0.05 (max)	0.05 (max)	0.20 (max)	0.40 (max)	0.40 (max)	0.40 (max)	0.30	0.30
Existent gum, mg/100 ml	3.0 (max)	3.0 (max)	5.0 (max)	7.0 (max)	7.0 (max)	7.0 (max)	7.0	7.0
Potential gum, mg/100 ml	6.0 (max)	6.0 (max)	8.0 (max)	14.0 (max)	14.0 (max)	14.0 (max)	14.0	14.0
Heat of combustion, Btu/lb	18,700 (min)	18,900 (min)	—	18,400 (min)	18,400 (min)	18,300 (min)	18,400	18,400
Gravity, $60^{\circ}/60^{\circ}\text{F}$	—	—	0.850 (max)	0.780 to 0.739	0.802 to 0.751	0.845 to 0.788	—	—
Specific	—	—	—	50 to 60	45 to 57	36 to 48	39 to 51	45 to 57
$^{\circ}\text{API}$	—	—	—	—	—	—	—	—
Viscosity, centistokes	—	—	—	—	—	16.5 (max)	15	—
-30°F	—	—	—	—	—	—	—	—
-40°F	—	—	10.0 (max)	—	—	—	—	—
Smoke-Volatility index	—	—	—	52.0 (min)	52.0 (min)	—	—	54.0
Smoke point, mm	—	—	—	—	—	19 (min)	20.0	—
Flash point $^{\circ}\text{F}$	—	—	110 (min)	—	—	140 (min)	110	—
Explosiveness, percent	—	—	—	—	—	50 (max)	—	—

The JP-3 specification then remained unaltered until May 1951, when the mercaptan sulfur content was limited to a maximum of 0.005 percent by weight. This revision resulted from corrosion difficulties, possible rubber swell problems, and objectionable odors that were being encountered during engine tests.

During the growth of the JP-3 fuel specifications, a great deal of opposition to the high volatility of the fuel was voiced because of the excessive entrainment (slugging) losses that occurred during rapid climb. Despite these losses, there was reluctance to decrease volatility because of expected difficulties in engine starting, cold-weather performance, and increased tank explosion hazard. The objections against lower volatility were mitigated by the results of engine performance studies that indicated satisfactory operation on a fuel similar in some characteristics to JP-3 fuel but having a Reid vapor pressure of 2.0 to 3.0 pounds per square inch. This range of vapor pressure represented a compromise between the desired engine performance and fuel availability. Because of this drastic change in volatility, the new fuel became known as JP-4 under the specification issued in May 1951. In December 1953, changes were made which included lowering the maximum limits on existent and potential gum and adding a smoke-volatility index to ensure clean-burning fuels.

The MIL-F-5624C specification was introduced in May 1955, and incorporated changes in volatility and specific gravity. These changes were dictated more by the desire for universal availability than by technical considerations. As emergency use would involve operation of aircraft on fuels available throughout the world, broadening of the specification was needed to permit engine development for the maximum variations in fuels that might occur. The current JP-4 fuel (under MIL-F-5624C) is accepted as the primary military fuel for turbojet aircraft.

An additional fuel, JP-5, has been established to control the properties of a special blending component for use in naval aircraft operations. This component resembles a high-flash-point kerosene and, in application, is blended 2 or 3 parts by volume with 1 part by volume 115/145 grade aviation gasoline. With the exception of a freezing point of approximately -60°F and a distillation point of 50%, the properties of these two components combine to meet the JP-4 specifications.

Recently, prompted by economic factors, a kerosene type fuel similar to JP-1 and designated ASTM (American Society for Testing Materials) Type A was proposed. At about the same time another fuel, ASTM Type B, resembling JP-4, was introduced. These ASTM Type fuels are a breakaway from existing military fuels and are being considered for use by most airlines entering the jet field. Some airlines are already operating on these new fuels which are still undergoing development and specification changes.

Knowledge of the physical properties of fuels is very important in the development of fuel system design. Equally important is knowing how a given physical property will vary with environmental changes—how properties such as density or volatility may vary with temperature.

Fuel density is of interest in airframe design since it controls weight loadings with completely full tanks and, when combined with the heat of combustion, it

is used in flight-range calculations. It is also a factor in the calibration of tank quantity gages and flow-measuring devices. Density is usually expressed in terms of true density (mass per unit volume) specific gravity relative to water at 60°F , or API (American Petroleum Institute) gravity. Fuel density decreases with increasing temperature.

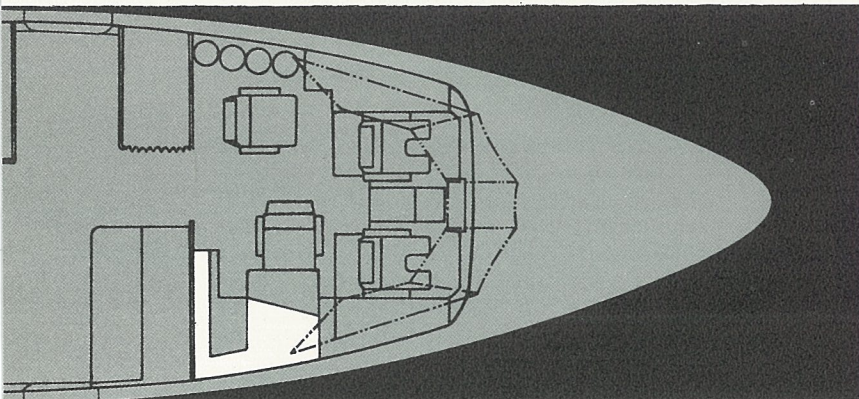
During airline fueling operations, each truck load of fuel is subjected to a fuel density check. Disregarding variables in fuel density could result in overloading the airplane or taking off with insufficient fuel. The Convair 880 has a normal fuel capacity (usable fuel) of 10,770 U.S. gallons, and the Convair 600, 15,108 U.S. gallons, all of which bears out the magnitude of fuel weight control. The following table gives specific gravity and weights for the different aircraft fuels.

SPECIFIC GRAVITY & WEIGHTS		
Fuel	Specific Gravity at 60°F	Weight in Lb/Gallon
Aviation gasoline (115/145 grade)	0.719	6.0
Kerosene (average)	0.803	6.7
JP-1	0.810	6.8
JP-3	0.760	6.3
JP-4	0.773	6.5
JP-5	0.827	6.9

The freezing point is another important factor in jet fuel specifications. Atmospheric temperature measurements have shown that ambient temperatures as low as -137°F may be encountered at high altitude. Even with aerodynamic heating in high-speed aircraft, skin temperatures and, in turn, aircraft tank temperatures might still be well below fuel freezing temperatures. In order to ensure reliable fuel system operation at altitudes where low temperatures are encountered and in geographical areas subject to low temperature ground conditions, aircraft fuel specifications limit fuel freezing temperatures to a maximum of -76°F for all fuels except JP-5 (-60°F), ASTM-A (-40°F), and ASTM-B (-60°F).

Viscosity data are necessary for the calculation of line pressure drop losses in aircraft fuel systems and may be required for the estimation of injection-nozzle performance. Information has been collected to indicate the viscosities that may be expected for a variety of fuels over a range of temperatures. Viscosities are not regulated for JP-3 and JP-4 fuels in current specifications, but maximum limits at low temperatures are established for JP-1, JP-5, and ASTM-A fuels.

Electrical properties of aircraft fuels have led to the development of the capacitance type fuel measuring system. This system consists of a series of probes (variable capacitors) which are immersed in the tanks, plus amplifiers, and a cockpit indicator. The cockpit indicator deflects proportionally to the height of the fuel in the probes and to the volume of fuel in the tank. The gages are calibrated to read directly in pounds, and the desired accuracy is ± 2 percent full scale.



Convair 880 Flight Engineer's Panel

The flight engineer on the Convair 880 is provided with an impressive group of panels containing more than seven square feet of instruments, lights, and switches. It is remarkable that such an array of dials and controls could be so simple despite its complex appearance, and a study of the panel quickly reveals the efficient grouping and placement of its different functions.

The flight engineer's panel is made up of several smaller panels, grouped in a pattern that best serves their purpose, and positioned in relation to the frequency of observation and adjustment by the flight engineer. For instance, the engine instruments which are under almost constant surveillance are at eye level and slightly to the right of the flight engineer. The hydraulic control panel, which requires only occasional attention, is located in the upper left-hand corner. The fuel control panel, containing the majority of controls and switches, is positioned at chest level within easy reach of the flight engineer.

Other systems represented on the engineer's panel are the air conditioning/pressurization control, electrical ac and dc power, and the communications panel. The flight engineer's lighting panel, his oxygen control panel, and his interphone panels are located in the lower right-hand corner.

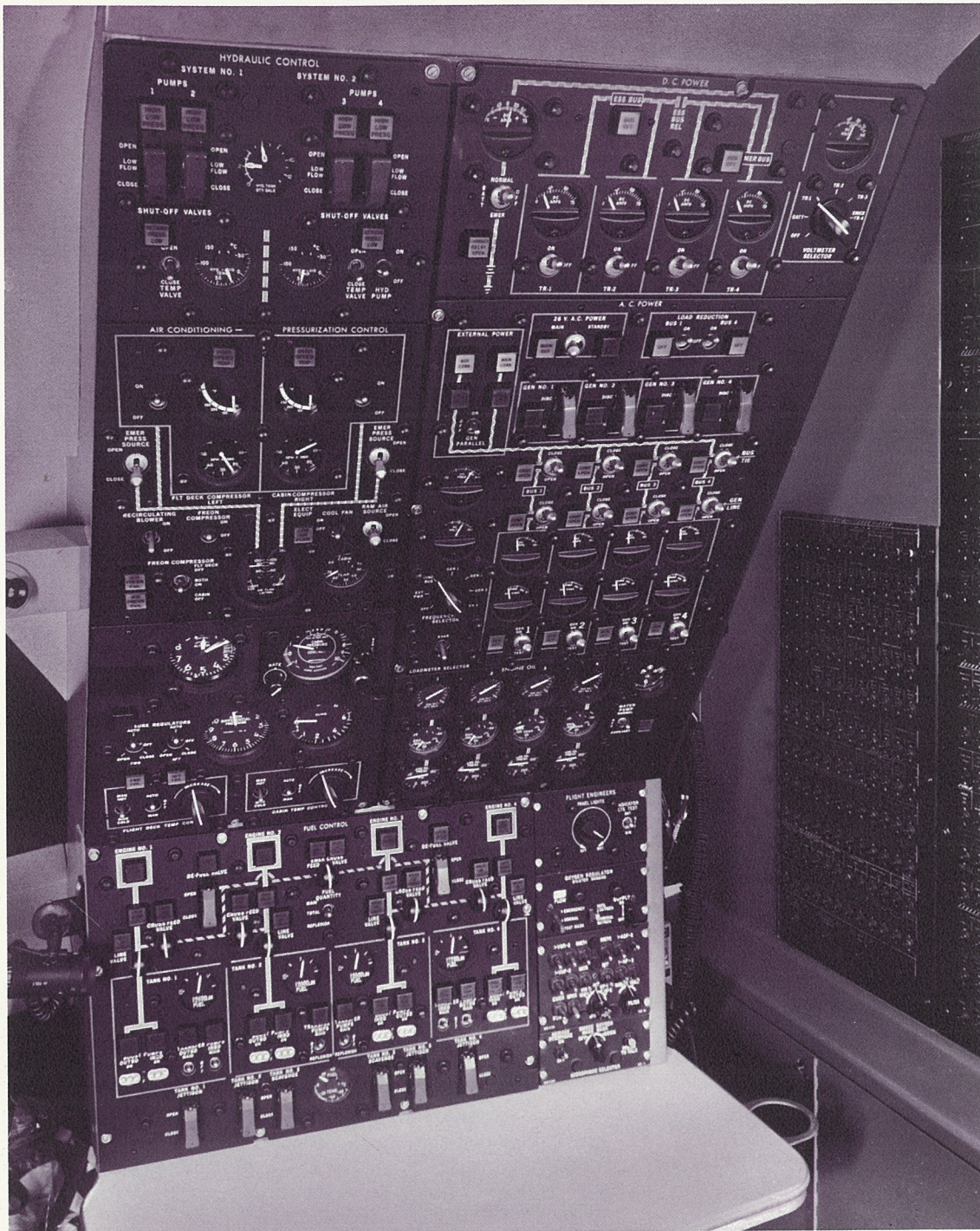
The flight engineer's panel on the Convair 880 might be likened to a crossroads of information. It is here on his "interchange" that the status of numerous systems on the airplane can be determined at a glance. Flow lines and circuit diagrams that are integrated with appropriate groupings of instruments, switches, and lights facilitate the monitoring of these systems. On the fuel control panel, the entire fuel system of the 880 is diagrammatically laid out on the surface. Controls and switches are positioned on the diagram just as valves and control units would be found in the actual fuel system. When a marker on a dial lines up with the diagram, fuel flows through at that particular point; when the marker is perpendicular to the diagram, the fuel is off.

The flight engineer's panels are manufactured to customer requirements and vary slightly in arrangement and content. Basically, the specifications are the same for the different airlines, and all incorporate Convair-developed design improvements. One notable improvement is the advanced installation design. To facilitate checkouts and maintenance, each group of panels, of which there are five, hinges outward exposing the underside for easy access. In an emergency, this can be accomplished in flight.

The pilot's and copilot's instrument panels on the 880 are illuminated by soft indirect lighting, while the engineer's panel is lighted by a system called "edge-lighting," due to layout requirements. To protect the crew's night vision during night flying, cockpit lighting is kept soft and at a minimum. This is essential to flying safety. After the crew has become accustomed to darkness, and acquired their "night vision," any bright or sudden light would lessen their ability to see in the dark, and it would take several minutes to regain that vision.

An edge-lighted panel is one in which light is transmitted by refraction through a clear transparent core. As with indirect lighting, edge-lighting enables instrument openings, switch locations, and callouts on the surface to be easily read either day or night without reflections or glare. In some cases, the instrument dials themselves are edge-lighted. The "880" panels are made of clear acrylic plastic opaqued with dull black except for lettering, diagrams, and switch and instrument openings. Around the switches and instruments, a thin ring of light is permitted to shine through to softly illuminate the immediate area.

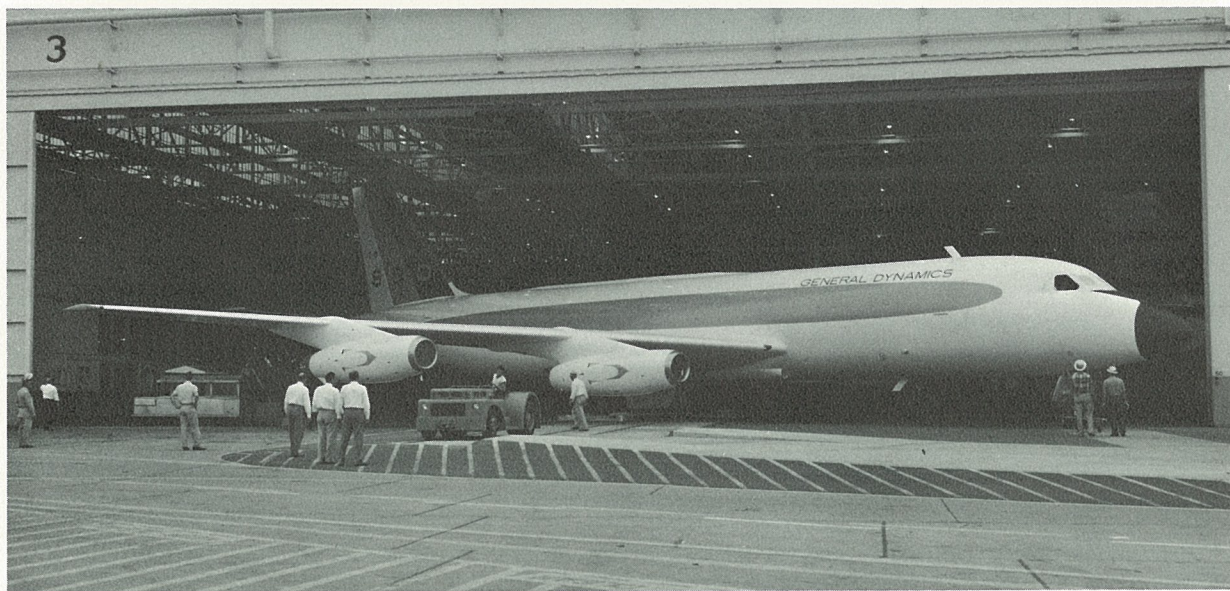
The panels are illuminated by minute electric bulbs, about the size of a pea, that are inserted into sockets fastened in the plastic. These lamps are carefully positioned a few inches apart to insure an even lighting and to prevent "hot spots" and faded-out areas. An interesting feature of these small lamps is the circuitry that



supplies their current. The lamps are inserted into the socket bulb first, making one electrical contact through a metal ribbon extending along the inside of the socket. A light-tight cap is placed over the socket, making contact between the center of the base of the bulb and a second ribbon leading through the panel. The sockets are connected by printed circuits of sintered silver material, which is silk-screened on the back side of the panel and embedded into the plastic, flush with the surface.

External electrical contacts of the edge-lighted panel are small bare plugs protruding from the back of the panel. The plugs mate into receptacles attached to a metal back-up plate to which the panel is fastened. Instruments, switches, and warning lights are also mounted on the back-up plate and fit through openings cut out of the edge-lighted panel. The back-up plate in turn is mounted to the airplane structure by corner screws and a hinge that enables it to be swung outward.

Because the wingspan of the Convair 880 is 120 feet, each "880" must move down the final assembly line at a 45-degree angle so as to clear the 100-foot semi-span of the building.



At the end of the line, each airplane is weighed on scales that are flush with the building floor. The airplane then moves at right angles to the assembly line, prior to being moved out of the building.

The No. 4 Convair 880, with protective covers still on the windows, appears to be "skidding" out of the building in this photo. Actually, the airplane's main gear trucks are riding on a special low dolly. The dolly's wheels are guided out of the building on tracks as the dolly is pulled by a tractor. When the aircraft is clear of the building, the tractor moves to the nose of the aircraft and tows the airplane to its desired position in the yard.

CONVAIR SAN DIEGO

CONVAIR DIVISION

GENERAL DYNAMICS CORPORATION

VOLUME XI

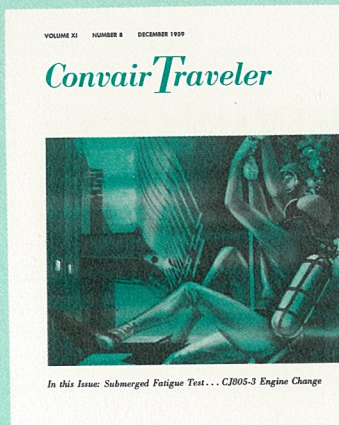
NUMBER 8

DECEMBER 1959

Convair Traveler



In this Issue: Submerged Fatigue Test . . . CJ805-3 Engine Change



OUR COVER

Convair engineers, trained as skin divers, inspect submerged Convair 880 test fuselage for signs of fatigue. Pressure testing program, comparable to 20 years of airline operation, has been completed.

Cover idea conceived by Norm Harrington and rendered by Harvey Adams.

Convair Traveler

VOLUME XI NUMBER 8 DECEMBER 1959

MANAGER, CUSTOMER SERVICE — J. J. ALKAZIN
 CHIEF, TRANSPORT SERVICE — L. J. BORDELON
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 ART EDITOR — N. J. RUTHERFORD

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Sam Urshan

A digest of operation and service published monthly by the Service Publications Sections of Convair Customer Service Department in the interest of Convair operators. Communications should be addressed to the Manager of Customer Service Department, Convair, San Diego 12, California. Information is to be considered accurate and authoritative as far as Convair approval is concerned. FAA approval is not to be implied unless specifically noted. Recipients of this information are cautioned not to use it for incorporation on aircraft without specific approval of their cognizant organization.

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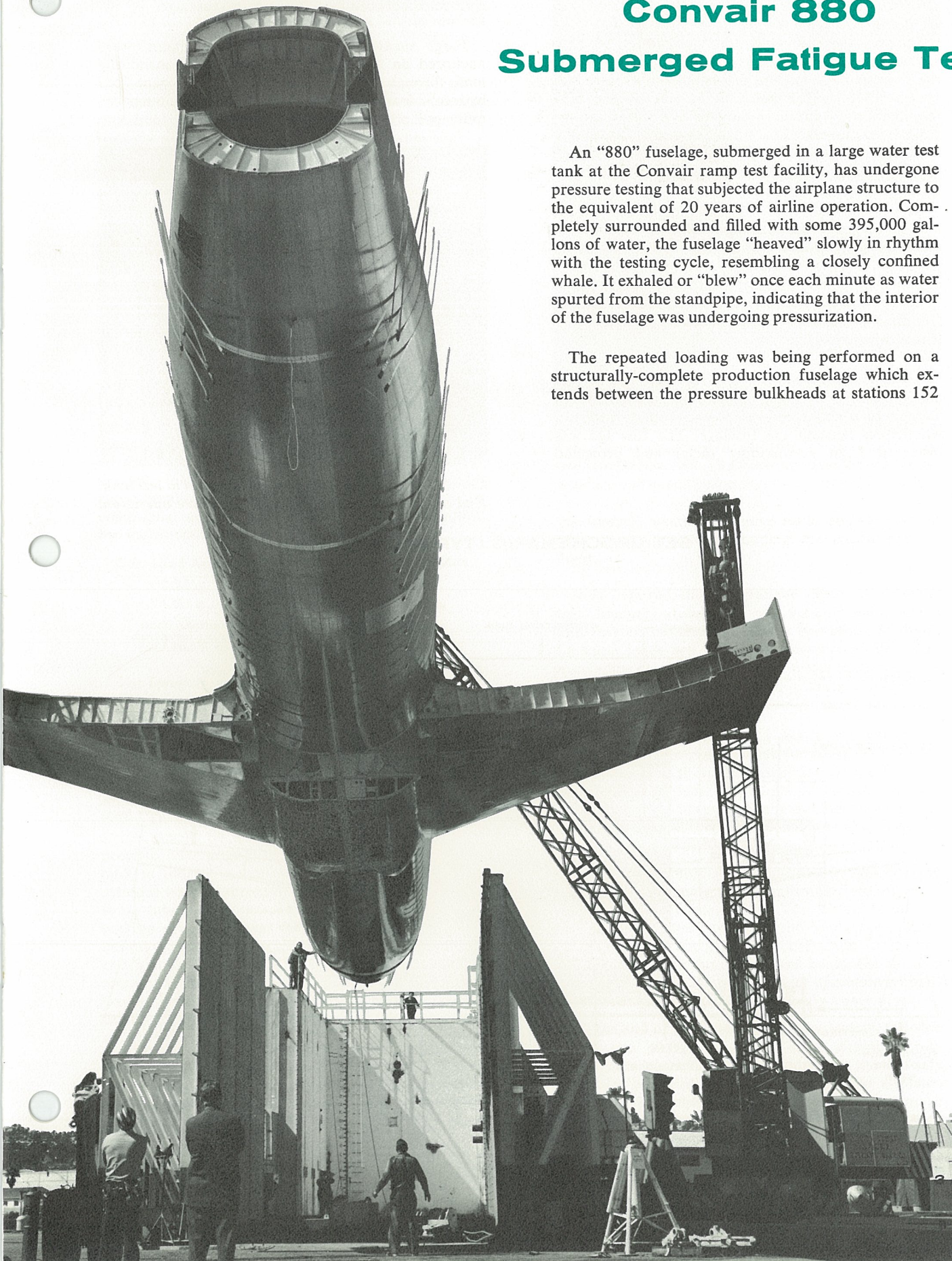
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Convair 880

Submerged Fatigue Test

An "880" fuselage, submerged in a large water test tank at the Convair ramp test facility, has undergone pressure testing that subjected the airplane structure to the equivalent of 20 years of airline operation. Completely surrounded and filled with some 395,000 gallons of water, the fuselage "heaved" slowly in rhythm with the testing cycle, resembling a closely confined whale. It exhaled or "blew" once each minute as water spurted from the standpipe, indicating that the interior of the fuselage was undergoing pressurization.

The repeated loading was being performed on a structurally-complete production fuselage which extends between the pressure bulkheads at stations 152



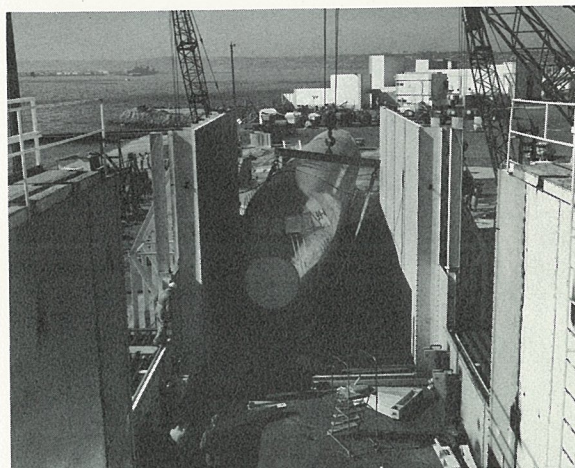
and 1373.95 (nose and tail cones are not included). All fairing attachment angles, brackets, and clips, and all doors and windows were installed to make the cabin pressure-tight. Only the 'stub' wings were installed. They included load-carrying structure between the front spar and landing gear beam, outboard to buttock line 310.00. The main landing gear beam and the interconnecting structure to the rear spar were installed, plus simulated main landing gear struts, so that landing loads could be applied at the wing-to-fuselage attachment.

The fuselage cleared the tank by ten inches in front and six inches at the rear. Sponson-like members on the tank sides enclosed the wing stubs, while steel members, attached to the wing stubs, carried the wing structure through to external "A" frames. The A-frame structure was designed to permit wing deflection and hydraulic cylinder down-load at either spar for controlled wing torsion.

Loads were applied through an arrangement of clad aluminum alloy straps attached to the fuselage, which were, in turn, connected via Micarta insulators to steel whiffletrees beneath the fuselage. The fuselage was insulated from surrounding metal and protected

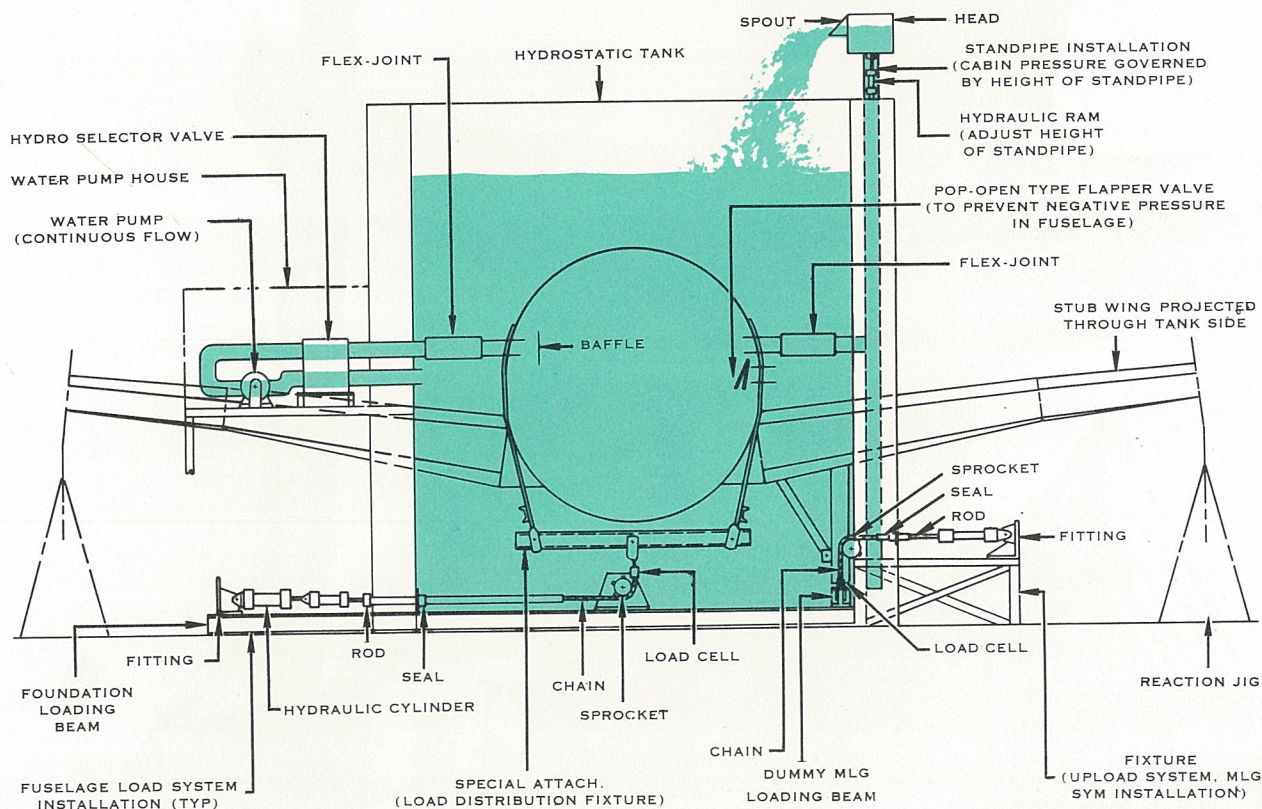
against electrolytic action by sacrificial zinc anodes connected between the tank wall and fuselage.

Large sheaves, equipped with belt chains, were anchored on the floor of the tank for transmitting loads through the sides of the tank. Two different sized hydraulic loading cylinders were connected in tandem to the pull rods, and cycling was arranged to load only



Convair 880 test specimen being positioned in test tank. End of tank has been removed to facilitate operation.

TEST SET-UP SCHEMATIC (TYPICAL SECTION)



one of these cylinders at a time. In this manner, the unloaded cylinder "bottomed out" and simply became a link in the pull rod. Two loads could thus be applied through the same strap-whiffletree-pullrod arrangement.

Hydraulic (water) pressure was applied to the inside of the fuselage to a pressure of 8.6 psi (maximum cabin pressurization relief setting). Because the fuselage is quite large in volume and stretches slightly when internal pressurization loading is applied, pumping water into the fuselage was necessary. A large water pump ran continuously and water was admitted via a large selector valve, actuated by a cycle timing device. The pressure requirement of 8.6 psi was established by permitting excess water to flow through a standpipe. Relief of pressure was accomplished through the selector valve. A flapper valve guarded against buildup of negative internal pressure.

A selected flight gust loading was applied by means of hydraulic cylinders. Following application and relief of these loads, landing condition loading and taxiing loads were applied.

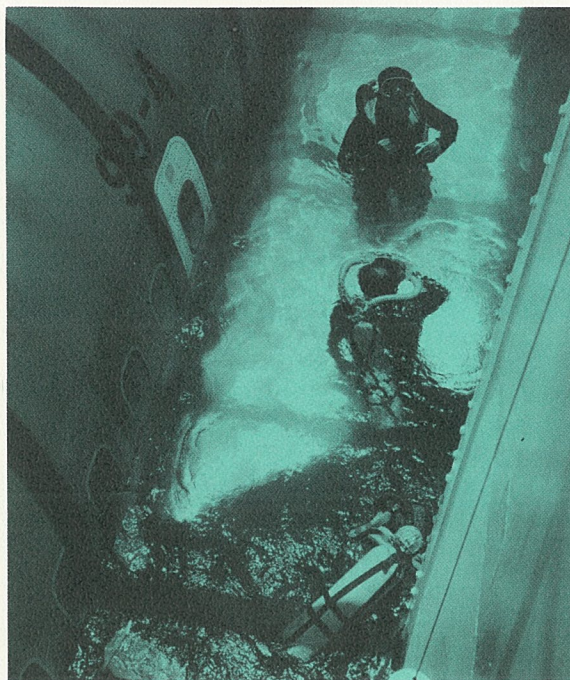
The flight gust loads had been arranged and were applied in a spectrum. The amount and repetition of loads applied corresponded with a pattern which might be encountered in operational flying. This spectrum applied a large number of relatively light gust loadings approximating the more abundant fair weather flying conditions, and a lesser number of higher loadings for inclement weather.

Gust Load Applied	Number of Applications
1.22 g	200
1.27 g	80
1.32 g	30
1.37 g	10

The foregoing loads were applied for the number of applications indicated and this routine was repeated six times. The spectrum was completed by applying a single load of 1.85 g. Each testing cycle marked a fully simulated flight of the aircraft.

The original conservative plan for the fatigue cycle testing indicated 20 cycles could be accomplished per hour. To insure that load applications over the test article would be applied as near simultaneously as possible, two large pipes were arranged around the tank in lieu of a central hydraulic manifold. Each cylinder was connected to the large pipe manifolds by short tubes or hoses. The time required for load buildup and release was very small. Because of this, it became practical to increase the cycle rate from the anticipated 20 per hour, to 60 per hour, or one per minute. With the test article flexibly supported and loaded, bending of the structure corresponded quite closely to actual movement under flight conditions.

Although the test arrangement would permit faster cycling, the large size of the fuselage might produce an unwanted effect. The aft end of the fuselage moved approximately nine inches during each cycle. If the cycle were more rapid, the water above and below



Skin divers inspect test fuselage while water rises in huge hydrostatic test tank. The flooding signalled start of the pressure and load cycling program on the Convair 880.

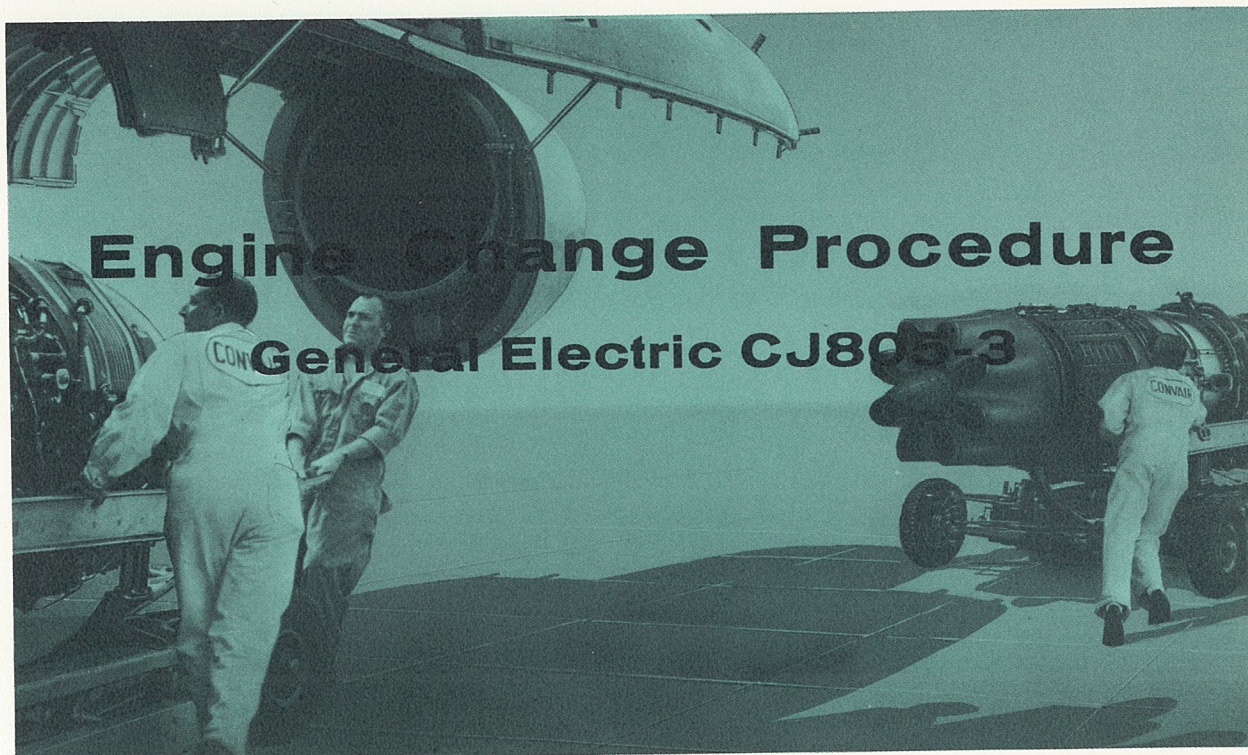
the fuselage would not move aside quickly enough. This would produce a loading not encountered in flight.

It is believed that the fatigue effect of applying flight loadings at this rate was actually more severe than that encountered in service operation. In flight, the same loads are softened somewhat by the compressibility of air and too, since water does not compress, hydrostatic testing adds a certain increment of shock.

The cycling continued 24 hours a day, with a scheduled shutdown each week for complete draining of the tank and thorough inspection of the fuselage structure using visual and X-ray techniques. Inspections were also made periodically by Convair engineers trained as frogmen to detect any possible signs of fatigue.

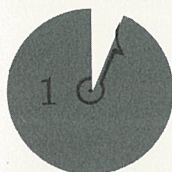
The test specimen was monitored by devices and recording instruments, which transmitted test information to a remote control room. The control room was filled with a battery of hydraulic load gages, water pressure and strain gages and deflection indicators. The airplane structure under test could not make a move or change in the normal cycle operation without the attending engineers being instantly aware of it.

At the end of the scheduled fatigue testing, fail-safe testing was phased in on this same airplane structure. These phases of testing confirmed the fail-safe structural considerations designed into the airplane, and aided in establishing limits of allowable damage for structural safety.

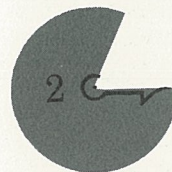


... A photographic analysis shows how engineering design saves "down time" on CJ805-3 engines ...

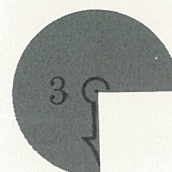
The process of removing an "880" engine breaks down into the following three stages.



Access — opening pod doors and removing rear pod lower section.



Disconnects — disengaging fluid, air, electrical, and engine control lines.



Removal — attaching support fittings, positioning engine stand, uncoupling the engine mounts and lowering the engine.

The photographs that follow show this procedure, item by item. The process is actually faster than this summary might indicate at a glance. Design objective for the installation was removal and replacement of an engine in 30 minutes. A Convair five-man crew proved by demonstration that this objective could be achieved.

Most of the line couplings are quick disconnects, and most are concentrated in a pair of panels, one on each side. Aft engine mounts require removing two nuts each; the forward mount is attached by one bolt. Reinstallation time, it has been found by experience, is very little more and often less than removal time.

Installing a completely built-up engine is essentially the process pictured in reverse. No rerigging of engine controls is normally required; connections must be leak-checked, however, and the engine must be "trimmed out" before flight with the aid of a precision calibration unit. The Convair 880 and General Electric CJ805-3 maintenance manuals have detailed instructions on removal, installation, control rigging, and trimming.

Access



To open pod doors, Hartwell latches are released, doors swung up, and support bars swung down and secured with ball-lock pins.



Aft lower pod section, under thrust reverser, is attached by four bolts, two on each side.

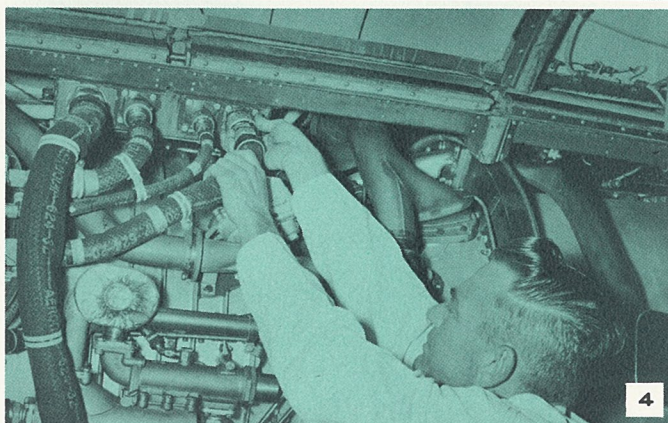
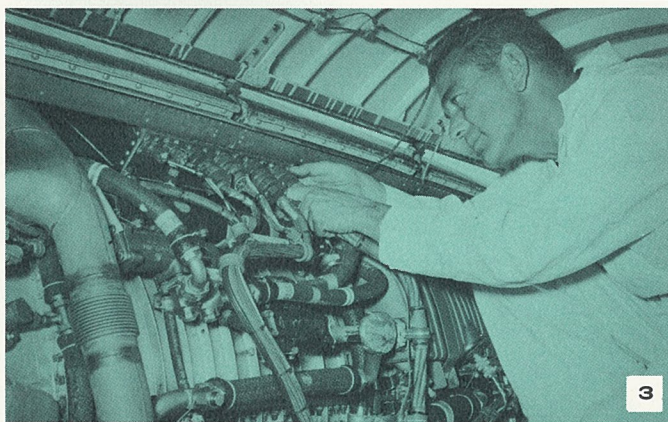
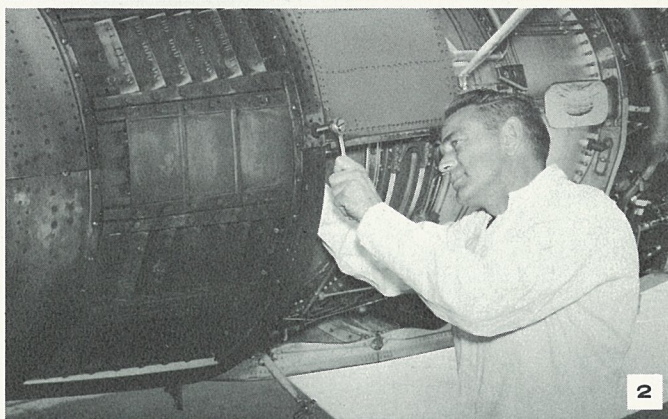
Disconnects

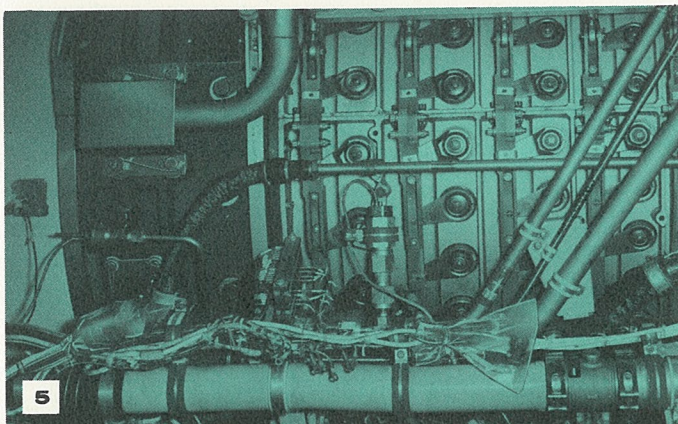


Six electric harnesses, pressure ratio static line, and one drain fitting are disconnected at a single panel on the right-hand side.

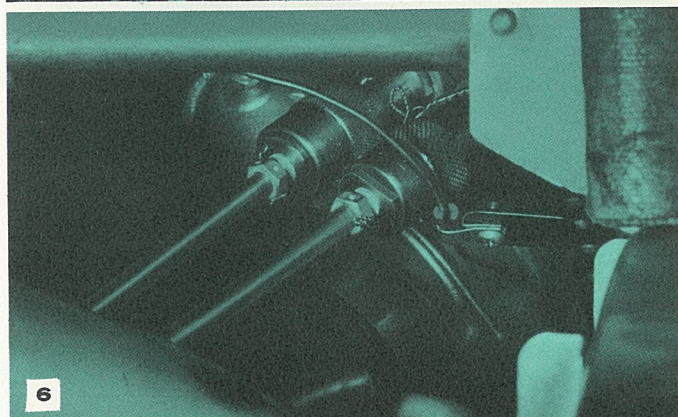


One fuel line, three hydraulic lines, and a drain are disconnected at the left-hand panel.

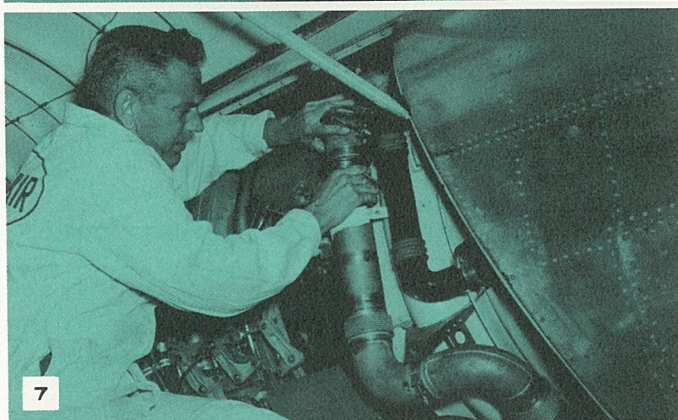




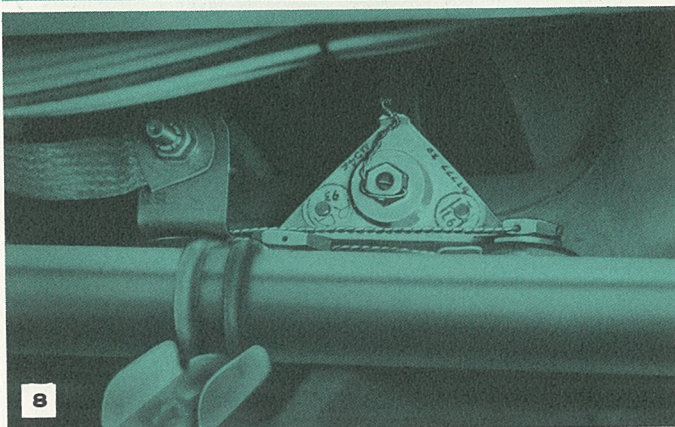
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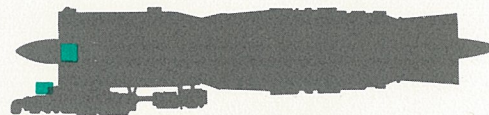
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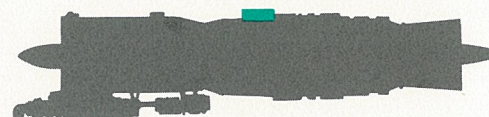
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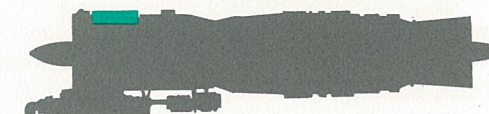
Inlet duct sensor harness to nose cowl is shown, already disconnected, at lower left-hand side. Bumper brackets, above, on forward compressor frame are removed for attaching engine stand ground support fittings.



Detail shows the two engine fuel control Teleflex disconnects; main bleed air line disconnect can be seen behind the teleflexes.



Starter bleed air line is disconnected. A similar Marman clamp joint (see Photo No. 6) disconnects engine from bleed air system.



Closeup shows forward engine mount "dog-bone" bracket, support link, and bond braid.



Closeup is of right-hand aft engine mount; left-hand is similar. The mounts are not disconnected until the engine stand is in place.

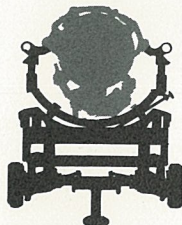
Removal



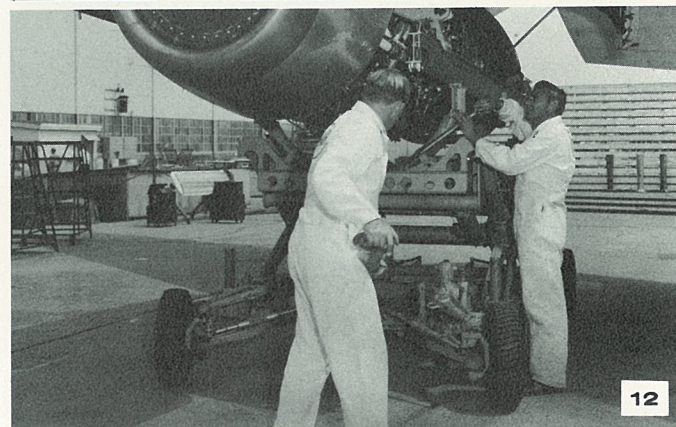
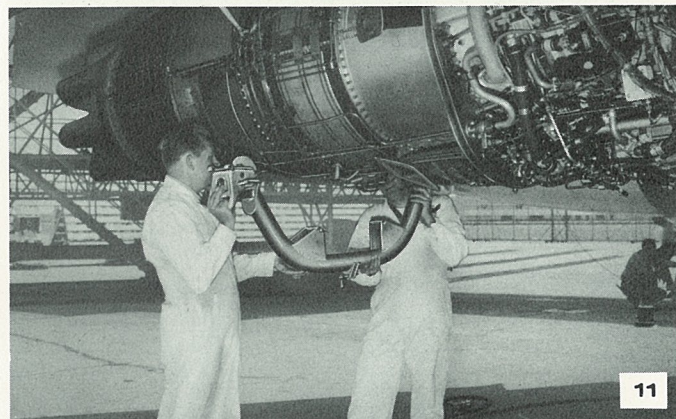
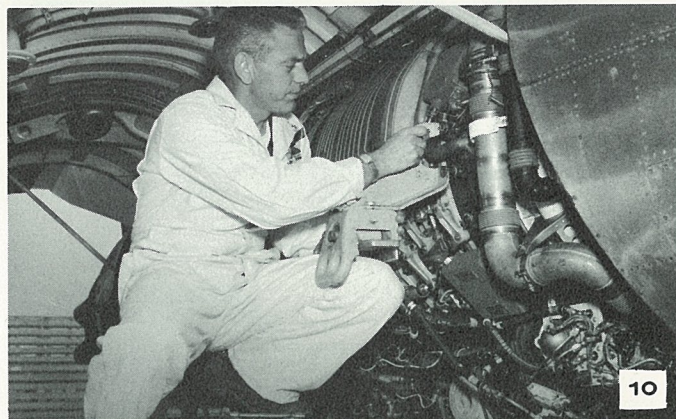
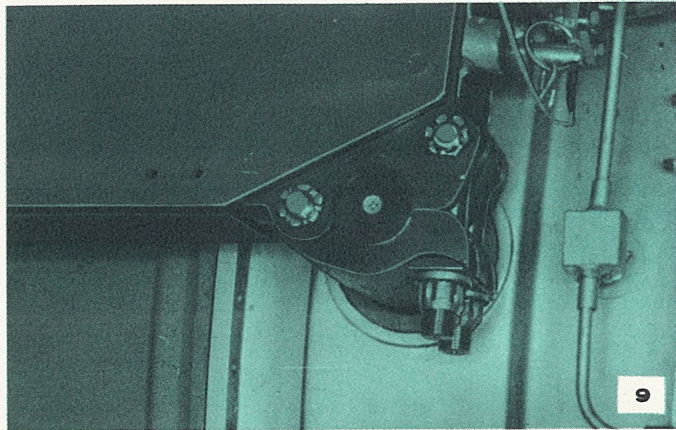
Ground support stand fittings are bolted to side mount pads on the compressor front frame, left and right, in place of the bumper brackets that were shown in Photo No. 6.

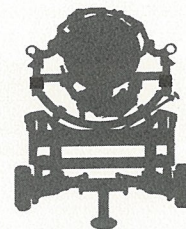
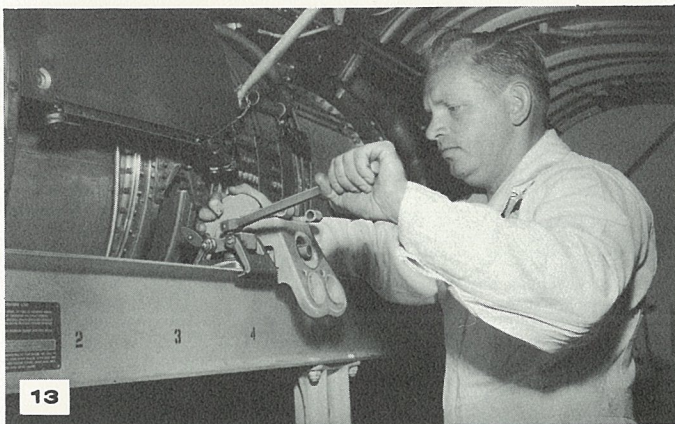


Aft ground support stand member attaches to bosses on lower segments of turbine frame.

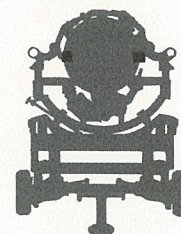
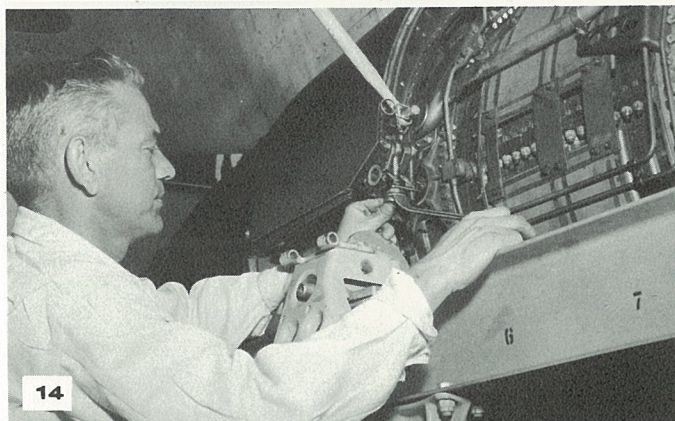


Stand is positioned carefully and raised until it just supports the weight of the engine. This is Air Logistics Corp. stand, with Convair-made fittings for the Convair "880" engine.

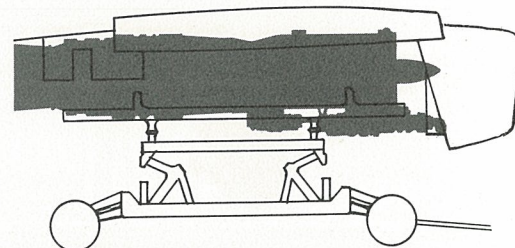
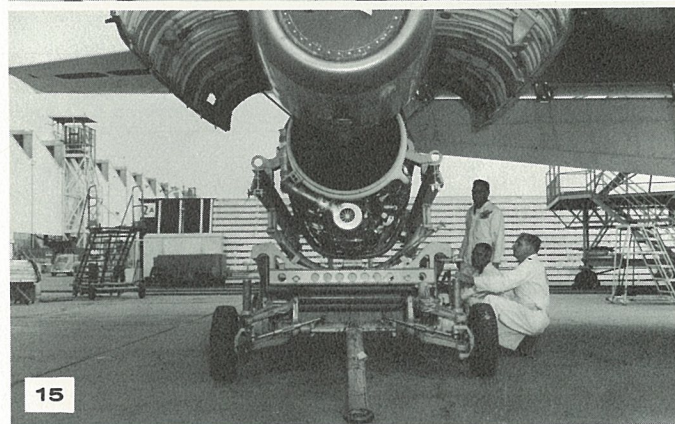




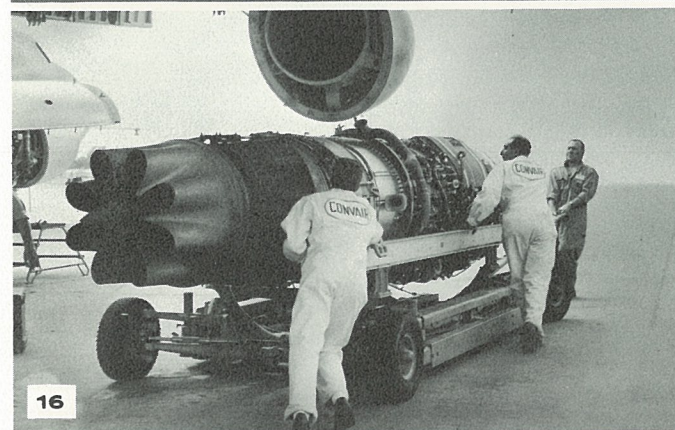
Support fittings are locked on stand rails.



Aft engine mount nuts are removed and lower half of clamp swung back to free trunnion. At forward mount, trunnion bolt is removed, to free the link from the "dogbone" bracket.



Engine is lowered, freeing side-thrust pin at 12-o'clock position on aft yoke; stand is backed until inlet nose cone fairing clears stub duct. Engine is then free of the pod.



Outboard engine can be wheeled away as shown; inboard engine must be backed far enough to clear nose cowl. Engine can be rolled or lifted to fixed stand for maintenance.

Convair 880 Engines Surpass Performance Estimates

During the past several months, the General Electric CJ805-3 turbojet engines on the Convair 880 have been tested extensively by both Convair and G-E. Speeds up to Mach 0.923 have been achieved and, in some instances, altitudes up to 50,000 feet have been reached. The "880" engines have proved themselves to be rugged, trouble-free jet-age power plants.

Boasting 2000 hours of factory testing, 1419 hours of test flying, and more than 425 hours of actual "880" operation (as of October 15), these engines have established a phenomenal record of safety, reliability, and versatility, and have left no doubt as to their exceptional suitability for airline use.

Last April, a 1000-hour flight test was initiated on two CJ805-3 engines to be used in direct support of Convair's own "880" flight test program. The two engines were installed on a USAF twin-engine Douglas RB-66, leased by the General Electric Company for the 1000-hour flight test. Prior to installation on the RB-66, one engine had recorded 2000 hours of factory testing, and the second engine had accumulated more than 300 hours of flight test time. The 2000-hour engine had undergone a preflight overhaul after which all major engine components, including "hot section" parts, were found to be in excellent condition and were reinstalled.

The engine pods and pylons were designed and built by Convair and closely resembled the "880" installations. Both engines were equipped with sound suppressors, one of which had more than 500 hours of previous flight time.

A great many planned air starts were made on each engine at operating altitudes up to 50,000 feet, all of which were successful. One engine was inspected after flying 418 hours without engine maintenance or adjustment, and was found to require no service. It was found that less than one pound of oil was needed for each flight hour.

Before the 1000-hour testing began, on January 20, the RB-66, using CJ805-3 engines, broke the intercity speed record between Los Angeles and Washington, D.C., by flying the route in 3 hours 36 minutes. The trip east was flown on kerosene and the trip west on JP-4 fuel. The change in fuel was made with no engine adjustment. The round trip took 8 hours and 36 minutes with the West-to-East time averaging 630 mph.

In August, General Electric announced that its two engines, powering the RB-66 had passed the 1000-hour flying mark on August 11. All flying had been done to simulate airline schedules and had covered more than 500,000 miles. The daily utilization averaged nearly 10 hours, and the airborne time for any one day was as high as 15 hours. This high utilization program required the pilots to work in shifts.

Periodic inspections revealed remarkable engine durability during the 1000 hours, with the engines remaining in excellent condition and requiring only minor parts replacement.

Convair's own flight test program has proceeded on schedule without a hitch. The "880" has not only exceeded performance guarantees, but has also surpassed drawing board performance estimates for speed, range, and takeoff and landing distances. The G-E CJ805-3 engines, with their high thrust-to-weight ratio, have been a major contributing factor to the "880's" remarkable performance and versatility. The light-weight engines permit increased fuel and payloads, thus making transcontinental as well as medium-range non-stop flights possible.

Takeoff tests show that, with its rapid acceleration, the "880" has the ability to take off from runway lengths shorter than the estimated 5450 feet (standard sea level conditions).

Landing tests indicate that, in using the aircraft brakes only, the estimated 5450-foot landing field length will be obtained. Such short landing and take-off distances will enable airlines to utilize many existing airport facilities without increasing runway lengths.

Other tests show that, without the use of brakes, the very efficient thrust reversers on the "880" slow down the 150,000-pound airplane from 100 knots to 40 knots within 3000 feet. Total reverse thrust was found to equal 48 percent of forward thrust.

Thrust reverser objectives set by Convair and the engine manufacturer were 5000 pounds reverse thrust, actuation time of not more than two seconds, and performance loss of not more than one percent of engine power. In actual "880" tests, however, reversers averaged 5400 pounds reverse thrust, actuation time less than one second, and performance losses under one percent. Thrust reversers installed on the "880" have run 700 cycles for five reverser hours during 489 engine hours.

Both thrust reversers and sound suppressors have outperformed factory guarantees. G-E's ejector-daisy-shaped suppressor was designed to effectively reduce sound, yet keep engine thrust losses less than 1.5 percent.

From a maintenance standpoint, the sound suppressors are remarkably durable with original units still operating without appreciable wear after more than 1600 hours (all totaled) of Convair 880 flight tests. Further proving their worth, the suppressors installed on the RB-66 have turned in a flight time total of 2200 hours to date with one unit exceeding 1000 hours of flight.

For almost a year, a USAF twin-engine RB-66, leased by the General Electric Company, has been used for flight testing CJ805-3 turbojet engines — sister power plants to the Convair 880 jet airliners. Encased in pods, similar to those on the “880’s,” and equipped with sound suppressors and thrust reversers, the RB-66 flew simulated airline schedules and wasted no time in proving that the CJ805-3 engines were tops in every respect.



The original plan called for a 1,000-hour flight test, but the final count ran to more than 1,419 hours. This impressive figure, coupled with 2,000 hours of factory testing and more than 425 hours of actual “880” operation, put the versatile CJ805-3 engines way out in front of all expectations, and established without a doubt their suitability for airline use.

The photo shows the CJ805-3 powered RB-66 being escorted by a Douglas XF4D test airplane, also equipped with a CJ805-3 engine. Both of these aircraft flew in support of Convair 880 testing.

CONVAIR SAN DIEGO

CONVAIR DIVISION

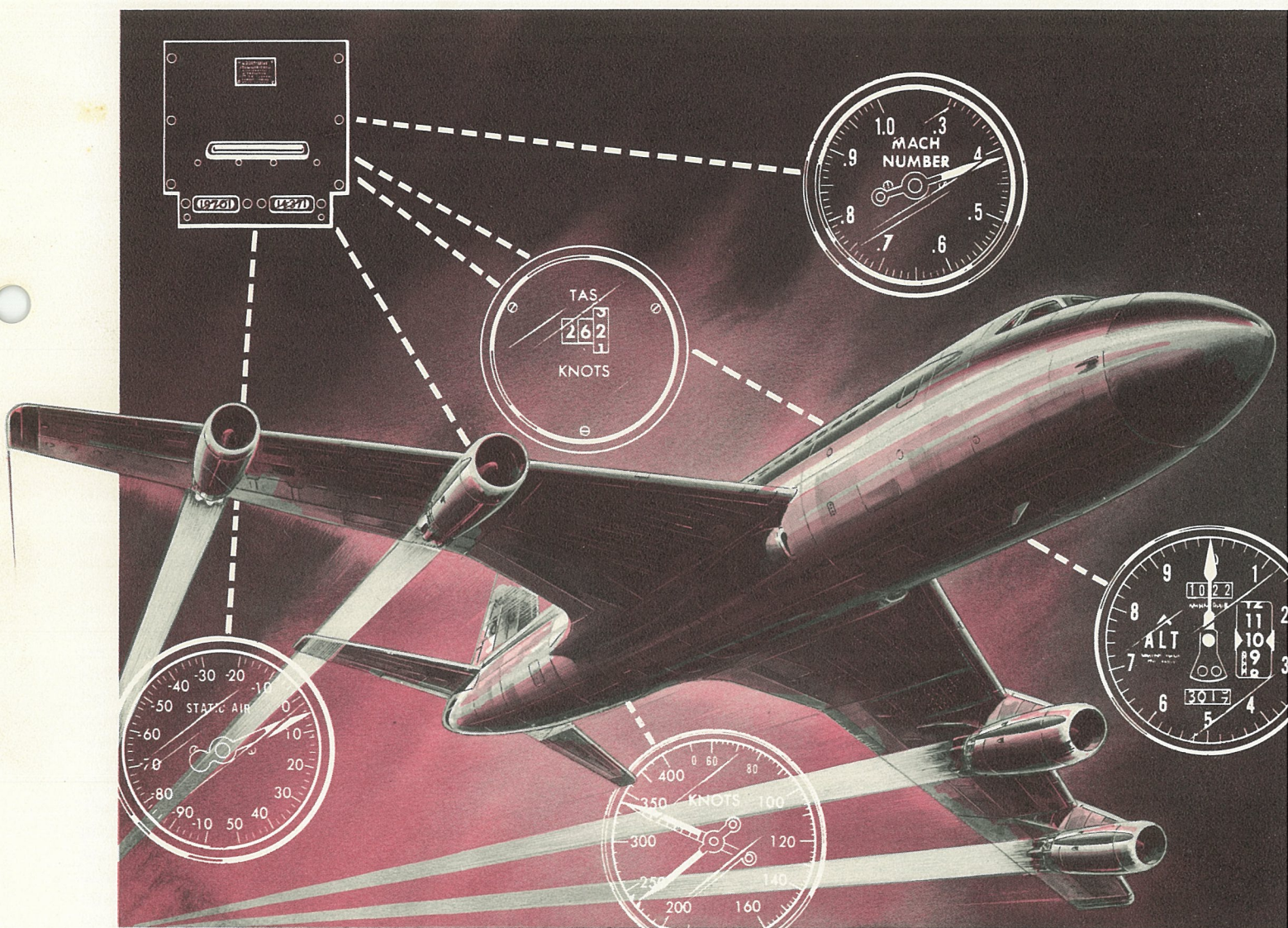
GENERAL DYNAMICS CORPORATION

VOLUME XI

NUMBER 9

JANUARY 1960

Convair *Traveler*



In this Issue: KIFIS...Kollman Integrated Flight Instrument System



OUR COVER

Aircraft instrumentation has had to progress rapidly to keep pace with the advancing designs of modern aircraft. Artist Bob Sherman has pictured the ultra modern Convair 880 under the control of its Integrated Flight Instrument System.

Convair Traveler

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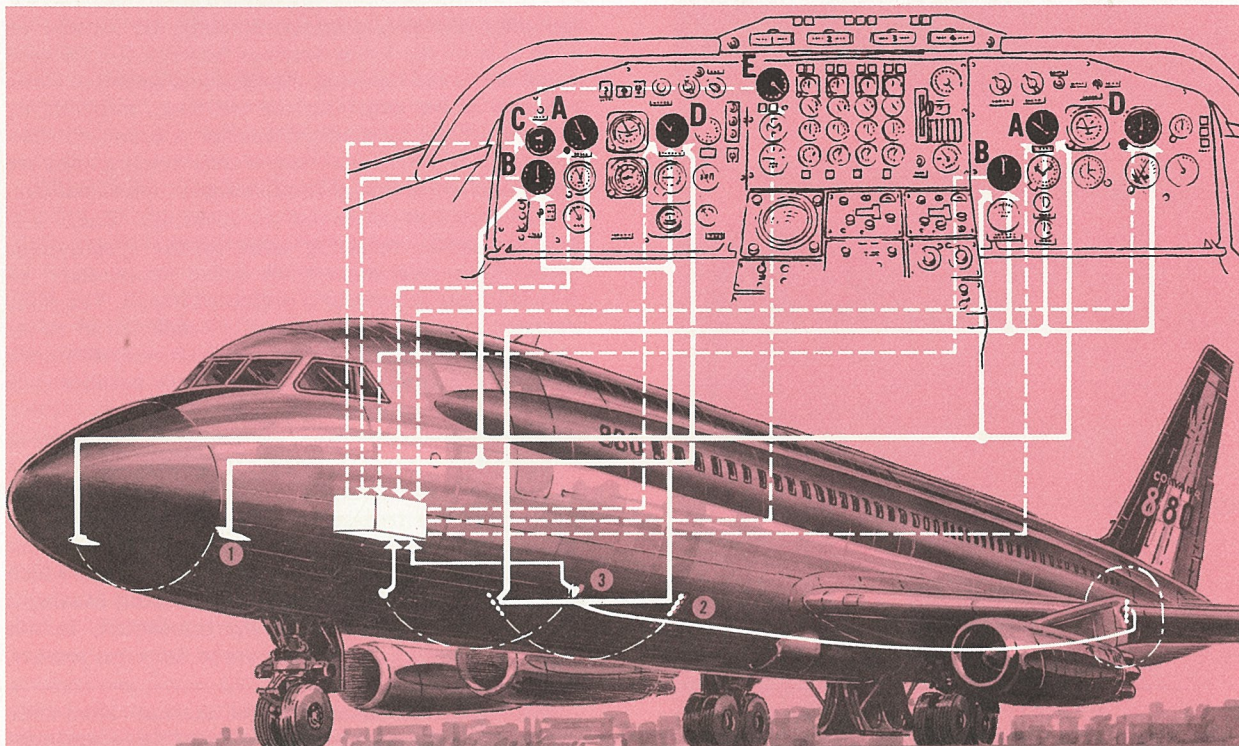
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K.I.F.I.S.

KOLLSMAN INTEGRATED FLIGHT INSTRUMENT SYSTEM - CONVAIR 880 / 600



Airspeeds, Mach number, outside air temperature, and altitude are computed from three sensors — pitot (1), static (2), and air temperature (3). Letters key pictures of instruments on pages 4 and 5.

Airspeed and altitude indicators in the Convair 880 and 600 jet airliners are highly refined versions of instruments that have not changed in basic principles since man first began to fly. Speed and altitude are still gaged by measuring ram air and static air pressures with aneroid sensors. Corrections must be made for local barometric pressure, angle of attack, temperature, instrument installation, and side effects of airflow outside the airplane. From these corrected figures, true airspeed must be calculated and maximum or optimum flying speeds derived for the airplane at a given altitude.

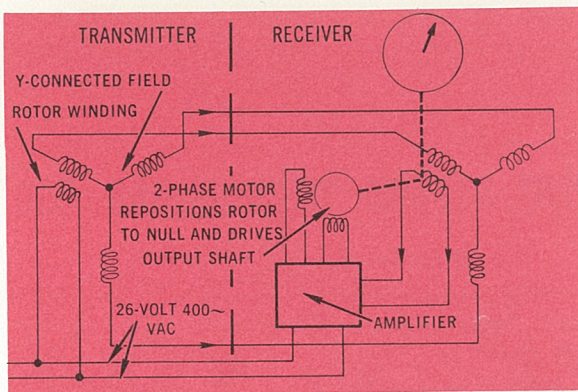
The difference today is that the pilot no longer has to figure all this out with graphs and pencil and paper. The instruments make the allowances, do the multiplication and extract the square roots, and show him the answer at a glance. By mechanical and electrical contrivances, aerodynamic equations materialize as miniature levers, gear trains, and bridge circuits; the solutions are worked out in terms of shaft rotations, to move pointers around dials.

Part of the computation is done within the individual instrument housings behind the flight compart-

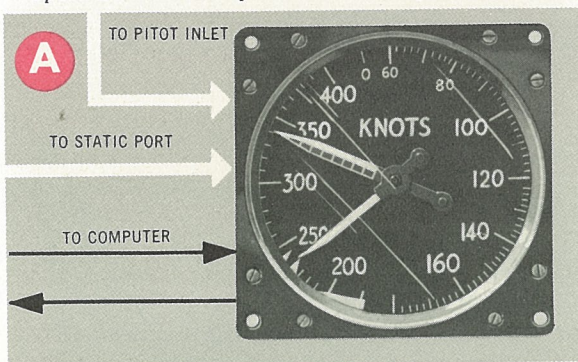
ment panels. The rest is performed in a computer unit in the electrical compartment, which interrelates the data from Machmeter, altimeter, and static air temperature bulb.

Five instruments — indicated airspeed, Machmeter, altimeter, true airspeed, and static air temperature indicators — make up the Kollsman Integrated Flight Instrument System, sometimes abbreviated to KIFIS. The three pressure-actuated instruments — airspeed indicator, Machmeter, and altimeter — are basically of standard design; without electric power, they will function as uncorrected conventional instruments, eliminating the need for standby instrumentation for use in event of power failure. The true airspeed and outside temperature indicators are dependent on electromechanical sources. Electrical data is available from the KIFIS for use with other flight or navigation instruments.

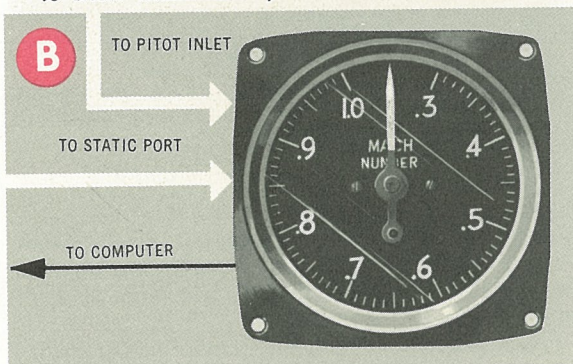
There are duplicate Machmeters, airspeed indicators, and altimeters — one set for pilot and one for copilot. Computer elements for these instruments are also duplicated, so that malfunction of one set does not affect the other.



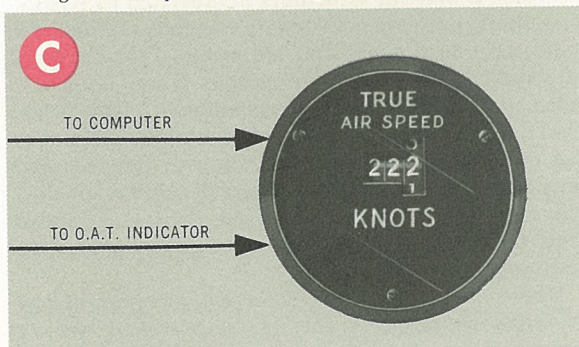
Synchrotel transmits data. Output shaft may operate instrument pointer or a computer rotor.



IAS indicator maximum-allowable pointer varies to show maximum speeds at various altitudes.



Machmeter provides output for use in computing true airspeed, true temperature, and altitude.



True airspeed indication, on pilot's panel only, is computed from Mach number, temperature.

The data from which the instruments operate come from pitot and static pressure ports, an angle-of-attack sensor, and a temperature bulb. Two pitot heads are located on the under side of the fuselage outboard of the nose wheel well doors. Pilot's Machmeter and air-speed indicator are supplied by one, the copilot's flight instruments and certain other instruments and equipment are connected to the other.

Flush static ports for pilot and copilot, and also for autopilot and pressurization systems, are located on each side of the lower fuselage between the forward cabin doors and the wing. An alternate source of static pressure is the unpressurized tail cone, available by actuating flight compartment static selector switches. The angle-of-attack and temperature sensing units are on the left-hand side of the fuselage in the slipstream.

The electrical portion of the Kollsman system utilizes transmitter-receiving units of the synchronous motor type (Kollsman trade name Synchrotel), of which a basic schematic is presented herein. The rotor elements, one of which is usually connected to an instrument handstaff, are energized by 26-volt 400-cycle a-c. Wye-connected field windings are paralleled as shown.

Identical field polarities are set up by induction in both units by the energized rotor windings. As the transmitter rotor is turned by the mechanism, shifting polarity in the transmitter field is duplicated by an identical shift in the receiver control transformer. This results in an error signal (in the receiver rotor) which is amplified and applied to the servo motor, causing it to duplicate the rotation of the transmitter. In this way, information can be conveyed between sensors, computers, and indicators.

Following are descriptions of the individual indicators, with some added discussion of the compensating mechanisms and circuitry.

The Machmeter indication is one that is not electrically computed or corrected. Pitot and static lines lead into the case, and diaphragms actuate a computing mechanism that yields a dial reading in Mach number — ratio of true airspeed to speed of sound at the airplane's altitude. The dial reads from 0.3 to 1.0, with a radial red line, which marks Mach 0.89 in "880" aircraft, Mach 0.91 in the "600."

Mach number has a direct relationship to errors inherent in temperature and static pressure sensing in a moving airplane. Therefore, the Machmeters include Synchrotel transmitters to make Mach number information available to the computers.

The basic outside temperature sensor is a resistance type bulb, mounted flush in the aircraft skin. The outside air temperature indicator is mounted on the left side of the instrument panel and is calibrated from -100°C to $+50^{\circ}\text{C}$.

The indicator uses, from the computer, a resistance value determined by Mach number and, by a bridge circuit, combines it with the information from the temperature bulb to provide a true reading. In the indicator is a potentiometer which provides a resistance, determined by outside temperature, to be used by the true airspeed indicator.

True airspeed is computed from Mach number and from outside temperature. The true airspeed instrument therefore receives its information directly from the air temperature indicator and from a Mach function derived in the computer. The instrument is mounted on the pilot's instrument panel. The reading is in digital form.

The IAS indicators — one for pilot and one for co-pilot — provide readings of indicated airspeed and for maximum allowable (Normal operating or V_{no}) speed.

The indicated airspeed reading is conventional, derived from a differential pressure mechanism that uses pitot and static pressures on a diaphragm to actuate a pointer calibrated in knots IAS.

Maximum allowable speed is indicated by a color-banded needle that is actuated by an altimeter-type static-pressure-measuring diaphragm. The maxima are in terms of equivalent airspeed up to a specified altitude, and in terms of Mach number above this level.

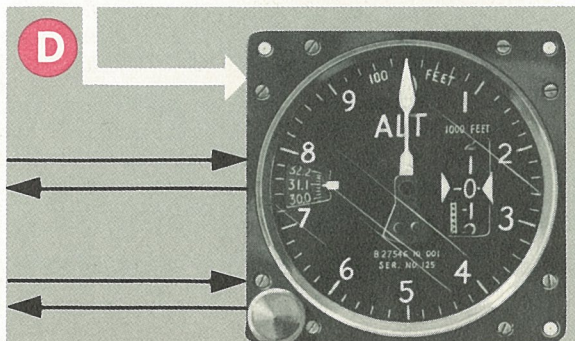
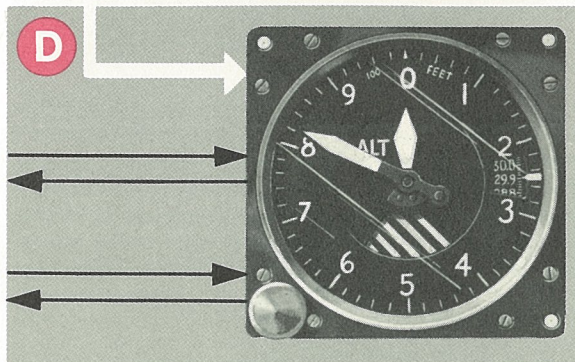
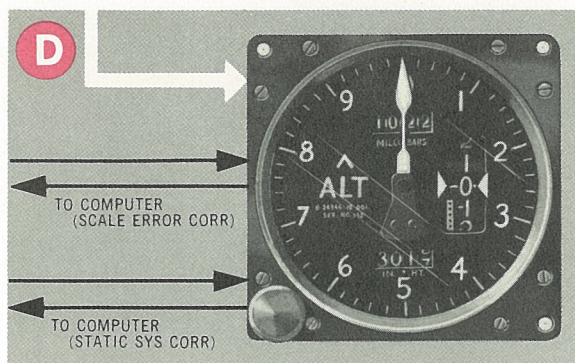
In the "880," the needle is calibrated to indicate maximum allowable speed in terms of the IAS resulting from a constant EAS of 375 knots up to approximately 22,900 feet, and in terms of Mach 0.89 above this altitude. In the "600," the maxima are in terms of the IAS resulting from an EAS varying from 375 knots at sea level up to 395 knots at the specified altitude (somewhat lower than for the "880"), and in terms of Mach 0.91 above this level. The needle will therefore normally move upward as the airplane climbs to the specified altitude, and then downward as IAS drops with constant Mach at higher altitudes.

Physical faces of the altimeters vary with customer preferences. Some 880 aircraft will have the conventional three-pointer dial, others the newer single-pointer dial with thousands of feet in a digital reading.

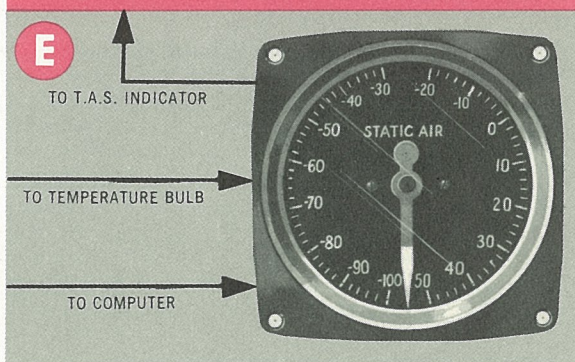
All Convair jet airliner altimeters, however, incorporate finely calibrated error corrective devices. One corrects for errors in the static pressure sensing system. These errors, standard in altimeters, are, for practical purposes, functions of Mach number and angle of attack. The mechanism centers about a three-dimensional cam, located in the computer unit. The Machmeter Synchrotel transmits a signal to the computer, which is used to operate a servo to rotate the cam as a function of Mach number; the cam follower moves radially across the face of the cam as a function of angle of attack, producing a signal proportional to static system error correction.

This signal is added to the output of a servo which compensates for error in calibration of the altimeter itself. The sum of these error corrections actuates a servo which rotates the diaphragm-operated altimeter mechanism, so that corrected altitude is shown on the dial. The Kollsman company claims an accuracy from within ± 30 feet at sea level to within ± 80 feet at 30,000 feet.

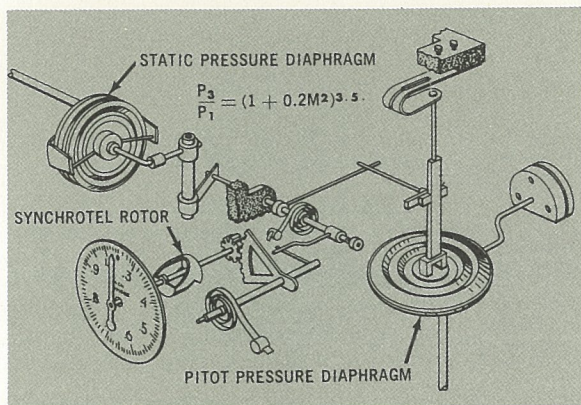
For those without technical background in recent instrumentation, the functional schematic diagram may give some general idea of how fairly complex algebraic formulas are given concrete form in mechanical and electrical devices.



These three types of altimeters are all being used in Convair 880 and 600 aircraft, depending on the preferences of the individual airlines.



Static air temperature (outside air temperature) indicator is on the center instrument panel.



MACHMETER OPERATIONAL SCHEMATIC

The word "computer" may bring to the layman's mind a picture of a ceiling-high array of blinking lights backed by miles of wiring and dozens of vacuum tubes. A computer may be as simple as a torque wrench. In the schematic exploded view of the Machmeter can be seen an indication of how

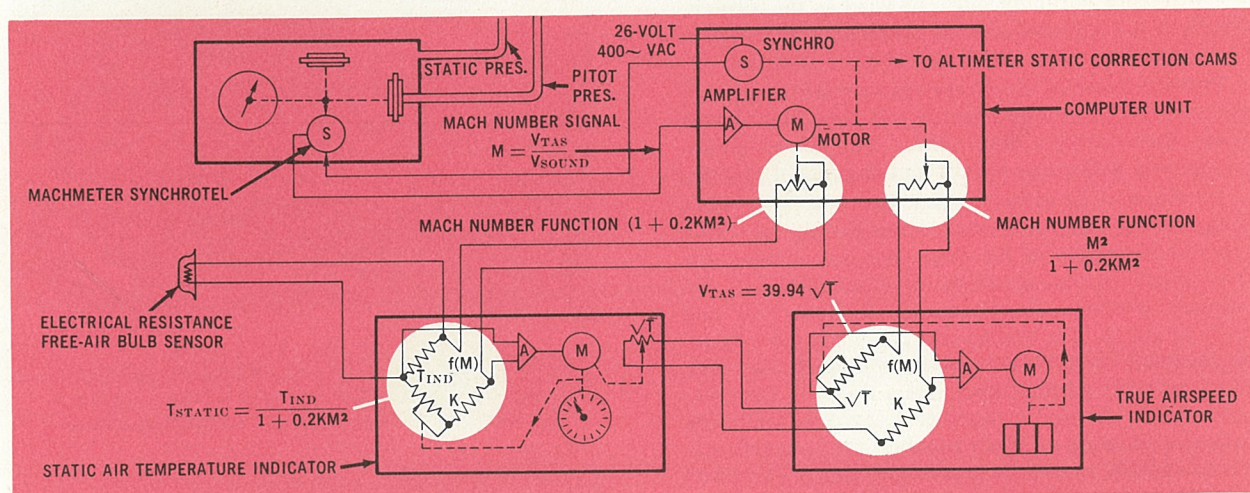
$$\frac{P_3}{P_1} = (1 + 0.2M^2)^{3.5}$$

looks in purely mechanical form.

accomplished by a bridge circuit, of which one leg is the Mach function; a second leg, the signal from the airstream sensor; a third leg, a calibrating resistor; and the fourth leg, a follow-up potentiometer. The motor that positions the follow-up potentiometer operates the instrument pointer to show true outside air temperature.

True airspeed is computed from Mach number and temperature by the equation $V_{tas} = 38.94M \sqrt{T}$. M comes from the computer, as stated; $\sqrt{T}$ is supplied by the temperature indicator, through a second potentiometer operated by the servo motor which operates the temperature pointer. The equation again is solved by a servo-balanced bridge circuit, the two functions forming two legs of the bridge; a calibrating resistor, the third leg; and a follow-up potentiometer, the fourth leg. The resulting signal drives a motor that operates counters to present true airspeed in digital form.

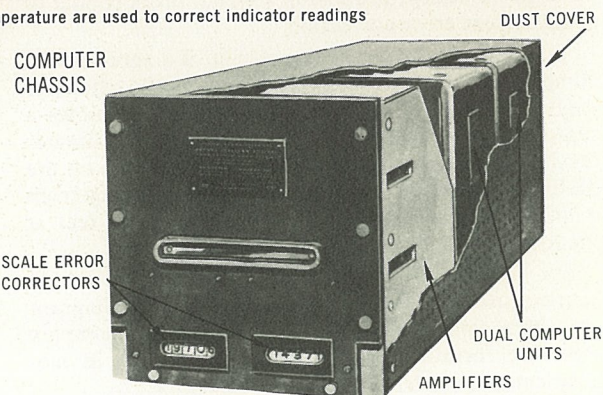
This type of computer is ingenious rather than complex, and demands a high degree of accuracy in both mechanical and electrical elements. Pinions are hardened steel, bearings are jeweled, dimensions and resistances are finely calibrated. Electronic elements are completely transistorized. To obtain utmost accuracy, a few parts of the system have been matched to certain other units, and care must be taken to see that such parts are not interchanged.



FUNCTIONAL SCHEMATIC (PARTIAL) showing how Mach number and ambient temperature are used to correct indicator readings

The Mach number (M in the formula), which expresses the ratio of true airspeed to the speed of sound, is relayed to the computer by Synchro. There, the receiver unit operates a pair of potentiometers, which provide two electrical outputs: a resistance equivalent to Mach function $(1 + 0.2KM^2)$ for use in computing true static outside air temperature from the reading picked up by the temperature sensor; and a different Mach number function M for use by the true airspeed indicator.

Static air temperature is the indicated air temperature divided by the function $(1 + 0.2KM^2)$. This is



Thrust Reversers and Sound Suppressors

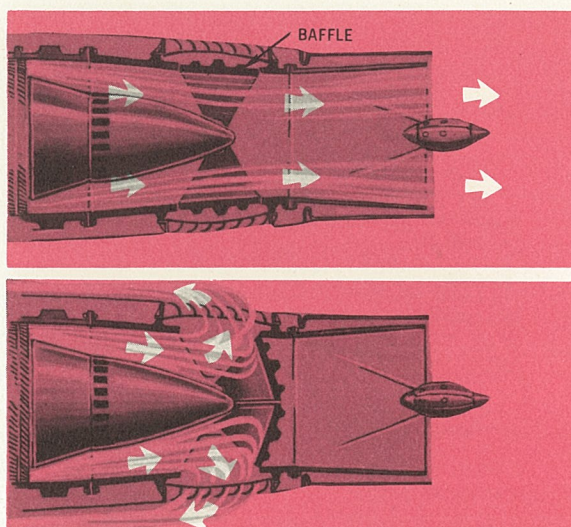
The General Electric Company, in close cooperation with Convair, developed an efficient thrust reverser and sound suppressor for installation on the CJ805-3 engine. The development program was initiated in 1957 and, in less than two years, production models of the thrust reverser-sound suppressor unit were ready for installation on the first Convair 880 jet airliner.

Thrust reversers brake the aircraft and shorten the landing roll, just as reversible pitch propellers perform this function on piston-powered aircraft.

The thrust reverser, constructed of corrosion-resistant steel, is an internal clamshell-cascade type, bolted to the aft end of the engine tailpipe. It consists of the tailpipe, blocker doors and mechanical linkage which actuate blocker doors.

Exhaust gases from the engine are diverted by two blocker doors that extend into the gas stream. When closed, the doors completely block the flow of exhaust gases, directing them through the turning vanes on each side of the reverser. With the reverser doors in the stowed (forward thrust) position, the doors conform to the shape of the tailpipe, allowing unrestricted flow of the engine exhaust gases aft through the reverser tailpipe and sound suppressor.

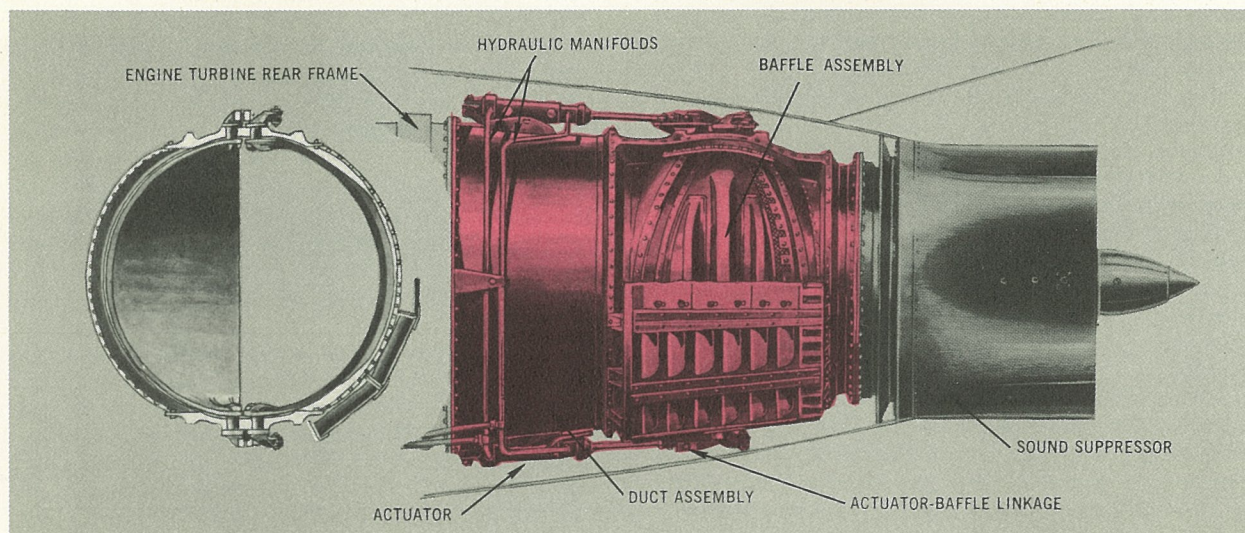
The fail-safe philosophy of the thrust reverser mechanism is that any single failure shall not prevent the thrust reverser from remaining in or near its last committed position. The doors are designed to have an overbalanced aerodynamic hinge moment to assure no inadvertent reversal in the event of a hydraulic and/or mechanical failure. A positive resultant hinge moment load is required to rotate the thrust reverse doors into the "In-Transit" range to reasonably assure no failures in transit.



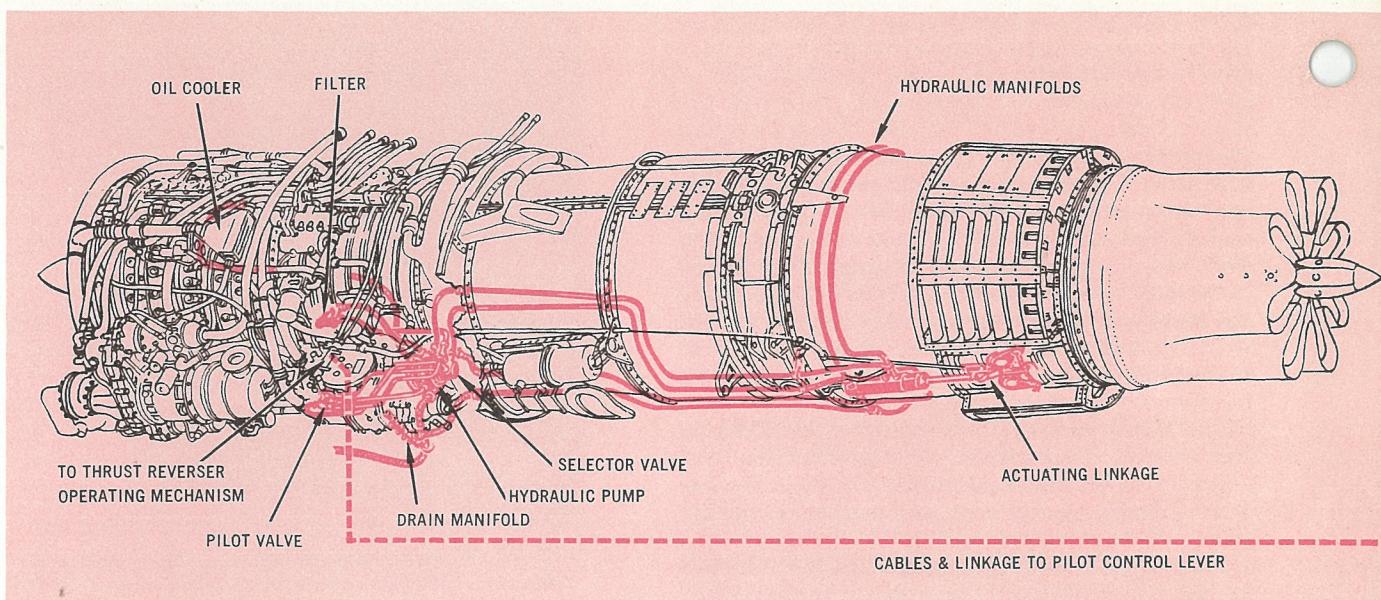
Top — Thrust reverser baffles in open position.
Bottom — Baffles closed for thrust reverse action.

Components of the thrust reverser system include a hydraulic pump on the rear accessory gear box; a hydraulic oil filter located on the compressor rear case; a pilot valve on the engine fuel control (used to signal reverser position); a multi-purpose reverser control valve, mounted in tandem on the reverser pump; two hydraulic reverser actuators, mounted at top and bottom of the tailpipe; and the constant-speed-drive fuel/oil cooler. The thrust reverser system uses the same oil, related reservoir, and equipment that is utilized by the constant-speed-drive system.

In operation, the thrust reverser is actuated hydraulically to either the forward or reverse position by the thrust reverse lever. In the normal power operating range, the reverser doors are held in the stowed position by oil in the low-pressure hydraulic system, an



Thrust reverser with section showing open and closed positions of baffles.



Thrust reverser showing major component parts.

irreversible overcenter link, the door "stowed" seals, friction, and the aerodynamically overbalanced doors. In the reverse position, however, hydraulic pressure is reversed to extend the doors. The pilot valve, mechanically linked to the thrust reverse lever transmits a signal to the selector valve. Filtered, high-pressure oil, supplied by the engine-driven hydraulic reverser pump is then directed to the actuators, extending the doors.

A hydraulically-operated selector valve in the control applies oil pressure to the head or rod end of the actuators, as required, and allows oil in the exhaust end of the actuator to return to the oil reservoir. A pressure relief valve, mechanically synchronized to the actuators, bleeds off hydraulic oil to maintain a predetermined holding pressure when the end of the actuator travel is reached. Oil bled from the hydraulic pressure lines is returned to the inlet of the hydraulic pump, and return oil from the actuator is routed through the constant-speed-drive fuel/oil coolers to the oil reservoir (CSD compartment).

The thrust reverse levers are mounted on the forward part of each power control lever assembly and rotate up and aft to activate the thrust reverser. With the power control lever in the idle position, aft movement of the thrust reverse lever will cause an interlock to engage that restricts any movement of the power control lever while the thrust reverse lever is in an active segment of its operating arc. A thrust reverse idle detent, incorporated in the mechanism, gives the pilot four pounds detent feel at the idle thrust reverse position.

Thrust reverser position is indicated by colored lights in the pilots' compartment, and is achieved through microswitches. A mechanical thrust reverse interlock is operated from the reverser actuators; neither the thrust reverse lever nor the power lever can be operated beyond the idle power region until the reverser doors are in their proper position. Actuation

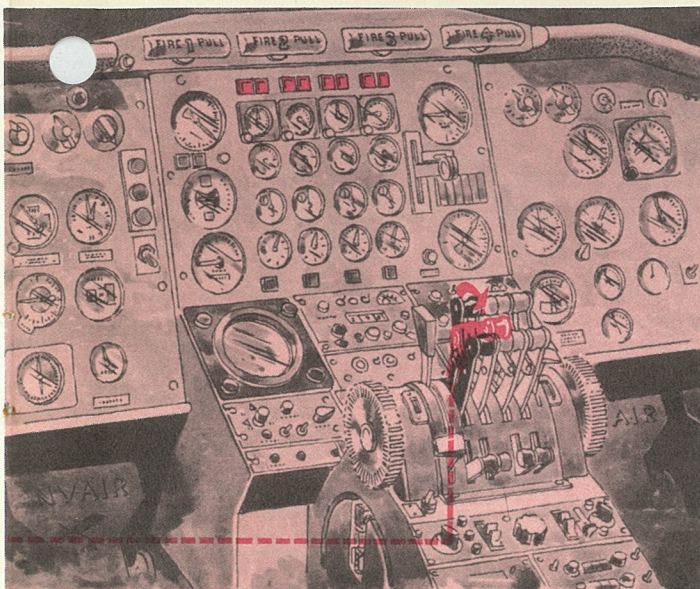
of the thrust reverser levers illuminates blue IN-TRANSIT lights which go out when the reversers are in either the extreme open or closed position. When the thrust reversers reach their functioning position, amber REV-THRUST lights illuminate. When the reverser levers are returned to IDLE, the REV-THRUST lights go out and the IN-TRANSIT lights come on until the thrust reversers reach their stowed position, at which time the IN-TRANSIT lights go out. The thrust reverser position indicating system operates on power furnished by the 28-volt, d-c emergency bus.

The thrust reverser is designed to produce at least 5000 pounds reverse thrust at sea level static conditions, ICAO (International Civil Aviation Organization) standard atmosphere, with the engine at 100% (7460 rpm). Performance loss of the engine with the reverser in the forward thrust position does not exceed 1%.

Reverse thrust can be obtained at any forward ground speed below 200 knots and in cross winds up to 40 miles per hour. The reverser and actuation system are so well designed, the doors can be moved from the forward to the reverse thrust position in one second. The reverser can be used for periods up to 30 seconds during aircraft decelerations on the ground or during ground checkouts. At speeds below 40 knots IAS, the reversers are not used at maximum engine power because of possible re-ingestion of exhaust gases.

The sound suppressor on the Convair 880 mates to the aft flange of the thrust reverser and forms the exit portion of the exhaust section. The exit configuration of the sound suppressor resembles the petals of a daisy, clustered around a center spike. This configuration provides rapid mixing of the exhaust gases with the surrounding air, thus reducing the noise level.

The development of the sound suppressor involved full scale testing of seven different types of configura-

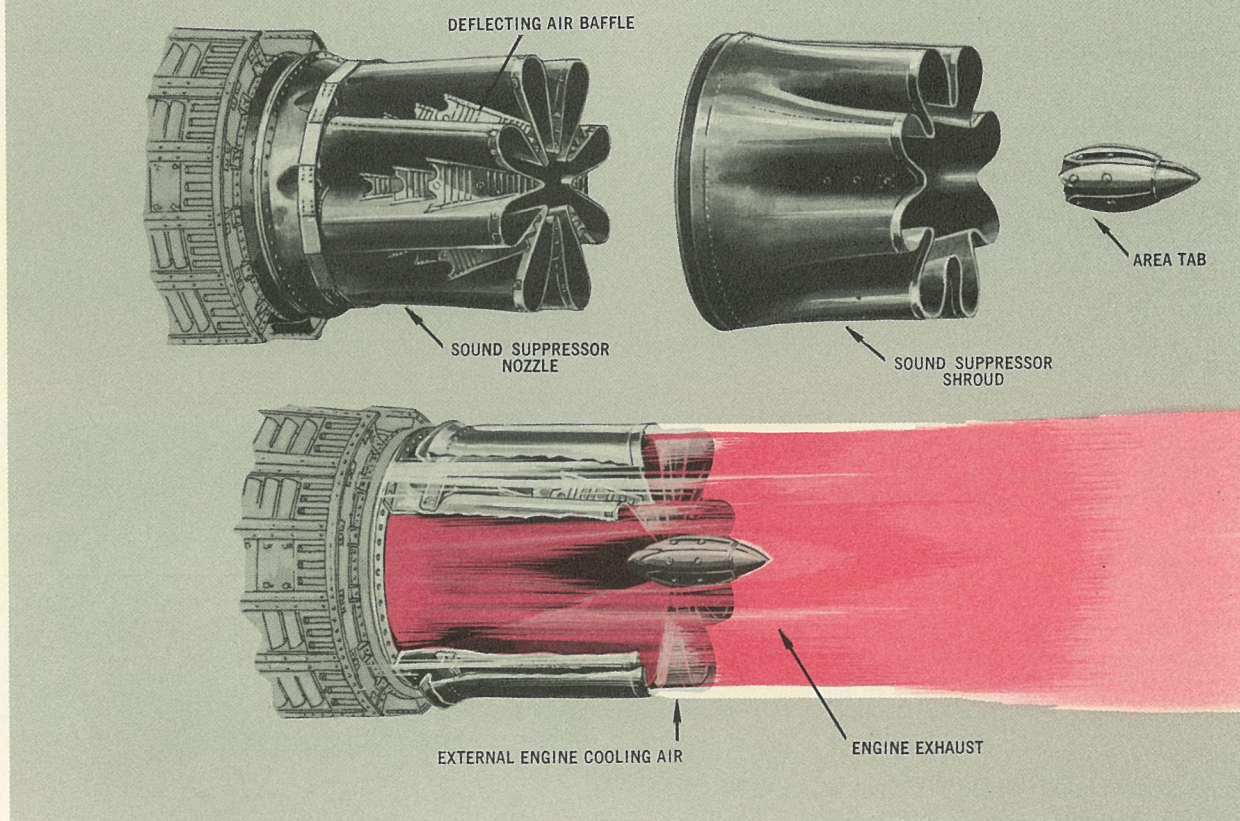


Color shows lever in thrust reverse position.
Black shows thrust reverser in OFF position.

tions. The current eight-lobed design was found to meet all of the Convair 880 requirements and was put into production. The design minimizes performance loss, is light in weight, and provides a structurally sound unit for long service life. The ejector fairing covering the exhaust nozzle further reduces aerodynamic drag.

The sound suppressor consists of an exhaust nozzle and a shroud, fabricated of welded stainless steel. The forward end of the shroud mates with the aft end of the airframe pod, and the flange at the forward end of the exhaust nozzle is bolted to the aft flange on the thrust reverser. The shroud follows the contour of the engine pod and serves as the external surface of the ejector nozzle. This type of nozzle requires a source of secondary air. At all conditions, the aft pod cooling air is routed between the shroud and the exhaust nozzle, thus increasing the mass flow of the exhaust gas stream. When operating at other than cruise conditions, air is supplied to the ejector from the four forward flush scoops by virtue of the ram pressure in flight and by ejector pumping action on the ground. The engine thrust losses with this ejector type of sound suppressor do not exceed 1.5 percent of the engine guaranteed gross thrust.

SOUND SUPPRESSOR COMPONENTS AND OPERATION



Metal Flow Spinning

Metal flow spinning, a process for forming hemispheres, cones, cylinders, and similar symmetrically turned shapes, is used in the manufacture of parts for the Convair 880 and 600. It accomplishes the making of parts by a cold plastic deformation of the metal, a new process of metal working that is coming into extensive use. It is sometimes referred to as "chipless" machining, because it can be used to form finished parts directly from flat or simple blanks. Heretofore, making these parts required extensive and costly machine cutting operations.

Metal flow spinning differs from ordinary metal spinning. Ordinary spinning is a hand-working art often requiring annealing of the metal between stages of rolling and shaping. In contrast, metal flow spun parts can often be turned out with a single pass of the metal flow spinning roller, because the flow spinning roller exerts not only a rolling action but a high shearing force which causes the metal to cold-flow onto the mandrel.

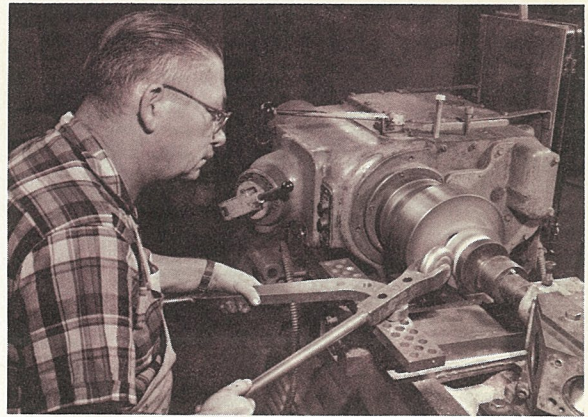
The actual working pressures exerted by the metal flow spinning lathe can be as high as 400,000 psi, when forming from thick metal blanks.

This newer application of spinning can be applied to a wide range of materials: metals such as aluminum alloys, mild steels, most types of stainless steel, Inconel, and such high temperature alloys as Allegheny Ludlum A-286 and Timken 16-25-6. Blanks may be made from mill-rolled sheet, plate stock, forgings, and, oddly enough, from castings.

High finishes and close tolerances are attainable. In general, greater strength and fatigue resistance results from this process.

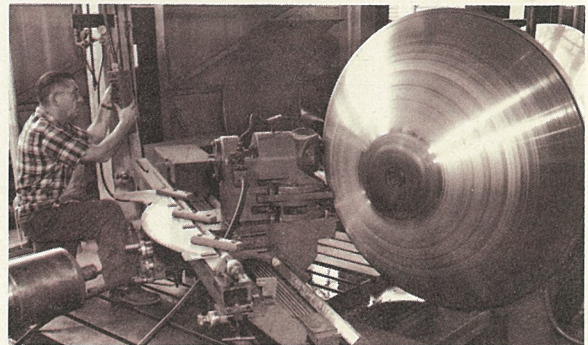
Convair's 880 design includes two rather large metal flow parts. One of these is the dome incorporated in the cabin aft pressure bulkhead. This is a spun section of a sphere, and measures 60 inches in diameter with a crown of 16 inches. It is formed from a flat blank of 0.172 inch bare 2024 aluminum alloy, and finished to 0.095 thickness.

The other parts are the two halves of the spherical stainless steel 50-gallon potable-water tank. These are spun from 0.050 pre-formed panned blanks, and from the hemispherical 30-inch diameter halves. The accuracy of the metal flow spinning is illustrated in this case as it is necessary to have the halves match perfectly for subsequent welding. The welded tank is subjected to a test load of 50 psi.



Metal spinning in the usual manner. Note long handled tool. Considerable skill is required.

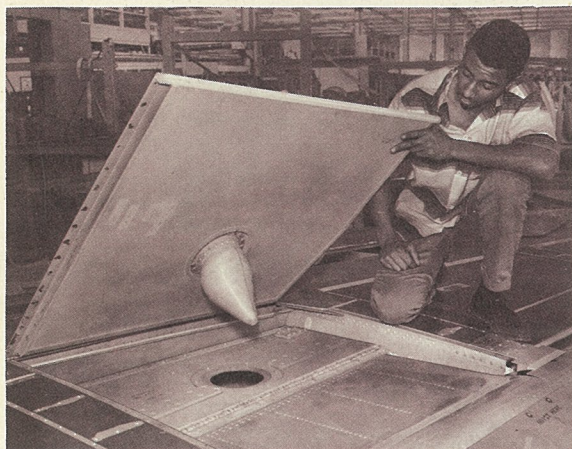
The "Floturn" lathe, which produces these parts, is located in Convair's plant 1. In addition to forming parts to 60 inches diameter, the lathe can produce parts up to 50 inches in length, and is equipped with a tracer attachment which makes it possible to form contoured shapes as well as conical shapes, with varied wall thickness. Parts similar to those used in the Convair 880 will also be used in the Convair 600. In addition, portions of the pods for the "600" aft fan engines are scheduled for metal flow spinning.



Metal flow spinning the "880" cabin aft pressure bulkhead dome from 0.172-inch aluminum alloy.



Machine spun halves are joined by welding to form the 50-gallon stainless steel water tank.



Fixed surface shroud raised to show regulator plug mounting and mating hole in balance board.

Flight Control Assist

The aerodynamic control forces acting on the tail surfaces of the Convair 880 in flight are quite large. Were it not for the fact that these are balanced down and trimmed out by assisting aerodynamic devices, the pilot would be hard put to exert enough strength on his controls to fly the airplane. As it is, the flight tabs, balance boards, and variable leakage regulator plugs combine in their action to remove excessive physical effort, providing the pilot with smooth integrated feel at the controls.

Spring-loaded flight tabs, located on the trailing edge of the rudder and elevator, are deflected by movement of the pilots' controls. The deflection of the tab is opposite that of the rudder or elevator movement so that flight tab movement assists in moving the main control surface. Physically, the pilot obtains approximately a 25-to-1 mechanical advantage by controlling the tab rather than the main control surface. In other words, a single foot-pound of pilot-applied tab hinge moment will produce 25 foot-pounds of aerodynamic hinge moment about the control surface.

Forward of the hinge lines of the rudder and elevator, inside the vertical fin and horizontal stabilizer, are the balance boards. They are kept inside to minimize aerodynamic drag, and because their operation is predictable throughout the flight range and their forces can be modified as required. The balance boards impart forces ahead of the hinge line on the movable surface. Thus they largely balance the forces which act on the exposed portion of the flight control surfaces.

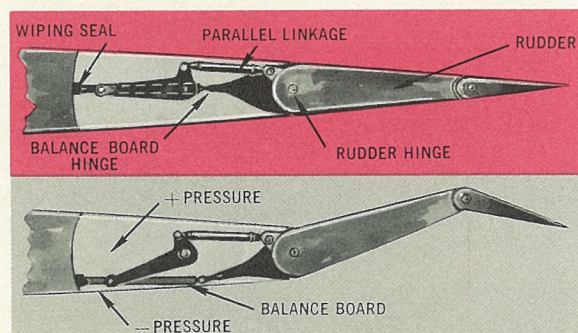
In principle, the balance boards act as aerodynamic pistons. The aerodynamic pressure built up on one side of the rudder or elevator when deflected, is allowed to enter the balance board chamber to exert pressure on the balance board. Similarly, the suction or negative pressure on the opposite side of the deflected control surface, draws from the opposite side of the balance board chamber. The combined pressure and suction forces acting on the balance boards are about equal to

the combined pressure and suction forces acting on the exposed control surface. Thus, the balance boards work automatically to lessen the necessary forces exerted by the pilot.

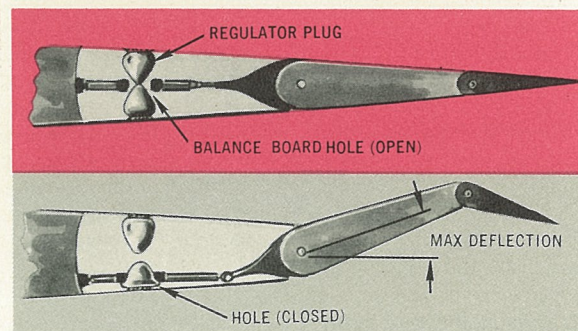
Balance board assist action is designed to permit full control surface displacement. The amount of automatic assistance from the balance boards at low angles of surface displacement is more than is required and would make cockpit control response too sensitive. For this reason, the variable leakage regulator plugs are installed.

The variable leakage regulator plugs are very simple and have no moving parts, yet they act to vary the force acting on the balance board. These cone-shaped plugs are mounted on each side of the stabilizer shroud. A circular hole with a seal is included in the balance board. At low angles of control surface displacement, the hole is wide open, relieving the pressure and suction delivered to the balance board chamber at low deflections. As the balance board moves to one side with larger control surface deflection, the tip of the plug enters the hole. In this manner, the hole is partially closed off. At full control surface deflection, the base of the regulator plug entirely seals off the flow of air between opposite sides of the balance board. The shape of the variable leakage regulator plugs permits just the right amount of force to build up for the desired feel at the cockpit controls.

The flight tabs, plus action of the balance board, give the pilot control over large control forces. The "tailoring" of the forces with the variable leakage regulator plugs causes the aerodynamic action to be smooth so that good pilot control "feel" results.



Schematic showing action of flight tabs, balance boards, and variable leakage regulator plugs.



Looking like giant cookie cutters, the daisy-shaped sound suppressors on the Convair 880 jet pods are easily serviced by an attendant standing on the ground.

Time and again the sound suppressors have proved their effectiveness in reducing jet engine noise to those levels comparable to conventional four-engine propeller-driver transports.



Also shown in the photo, directly forward of the sound suppressors, are the thrust reversers. These units, by virtue of their thrust-deflecting vanes, enable the 75-ton "880" to slow from 100 knots to 40 knots within 3000 feet of runway. This performance permits the Convair 880 to operate in and out of existing airports previously designed for four-engine propeller-driven airliners.

After hundreds of hours of operation, the sound suppressors, thrust reversers, and General Electric CJ805-3 engines have proved to be a virtually trouble-free combination, requiring the barest minimum of maintenance and servicing for continuous peak performance.

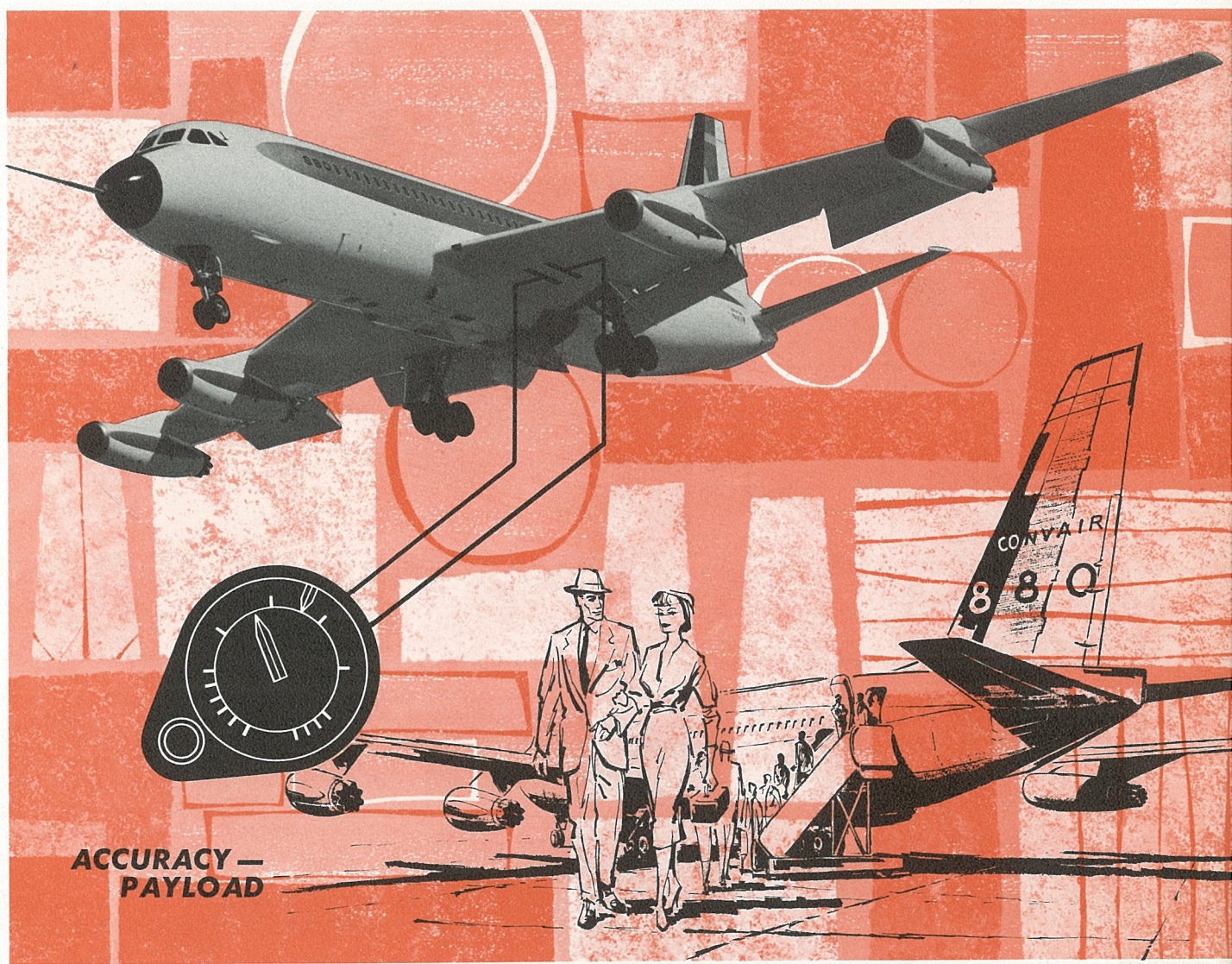
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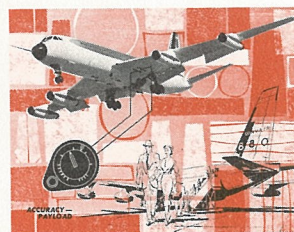


**ACCURACY —
PAYLOAD**

In this Issue: Simmonds Fuel Gaging System — 880/600

VOLUME XI NUMBER 10 FEBRUARY 1960

Convair Traveler



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OUR COVER

Artist Jack Davis emphasizes fuel gaging accuracy versus payload in his dramatic cover illustration of these important design factors engineered into the Convair 880/600 jet airliners.

Convair Traveler

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Simmonds Fuel Gaging System

880/600

The Convair 880 jet airliner carries up to 70,000 pounds of fuel — approximately six times the Convair-Liner maximum. Fuel-to-payload ratio is correspondingly high, and accuracy in fuel gaging is correspondingly more important. When a jet transport pilot adds up his gross weight for a maximum-load takeoff, his percentage allowance for possible system error must be low; if it isn't, the error allowance may be in thousands of pounds rather than hundreds.

To prevent needless sacrifice of payload, and to make possible safe fuel scheduling in flight, the Convair 880 and 600 transports have gaging systems as accurate as they can possibly be made, in the present state of the art. Where the "Mil-spec" design requirement (MIL-G-7818) for a twin-engine airplane was approximately 3½% maximum system error, the objective for the Convair jet aircraft is an accuracy within 1%.

This is a task of formidable complexity. Gaging systems, almost universally based on electrical capacitance, depend on dielectric and chemical constants that are never quite constant. Quantity gages depend on depth gages; in a wing tank, an inch difference in fluid level at midpoint may represent 200 gallons, at another point 50 gallons. Irregularly shaped tanks require multiple sensing points. Airplane attitude and wing deflection complicate the problem.

The gaging systems worked out for Convair 880 and 600 transports are supplied by Simmonds Aeroaccessories, Inc. They provide: (1) flight compartment readings for fuel quantity in each tank, and total fuel aboard; (2) wing refuel panel indicator readings of equal accuracy for quantity in each main-replenish tank system; and (3), an automatic cutoff in connection with the pressure refueling system for filling each tank pair to a specified level.

BASIC CIRCUIT

There are a total of 48 capacitance-type probes in "880" wing tanks. In the center fuel cells of the "600"

are 6 additional probes, plus 6 in the anti-shock bodies.

Each probe is "characterized" — individually profiled to match the tank contour. The probe consists of two concentric cylindrical tubes, separated by a comparatively large air gap.

Basic material of the tubes is epoxy-impregnated Fiberglas. The capacitive element is a silver surface film, deposited on the Fiberglas in a pattern that is generally spiral. Profiling for tank shape is effected during manufacture by a photochemical process. Holes through the outer tubes allow free flooding of the gap between conducting surfaces.

Electric power utilized is 115-volt 400-cycle ac. The dielectric constant of petroleum is approximately twice that of air. Since ac current flow through a capacitor varies directly with dielectric constant, current through the probes is a function of the height of the fluid level between inner and outer tubes.

All probes in any one tank — as many as nine in outboard main tanks — are paralleled. The sum of these capacitances, as measured by the total current through the probes, is thus a measure of the amount of fuel in the tanks.

The method by which current flow through the probes is interpreted in a reading on an instrument dial is on the principle of a continuously rebalanced inductive bridge circuit, in which capacity of the tank unit is constantly compared with a fixed-capacitance reference capacitor. The voltage signal resulting from the difference in capacitance is amplified to operate a motor-driven potentiometer, which restores the inductive balance, and at the same time operates the indicator mechanism.

Flight compartment indicators in the 880/600 have a 180° pointer dial in the top half of the face. More precise readings are given on counters in the lower half of the face. The three-digit counters show fuel quantity in 100-pound increments. The motor that operates the potentiometer wiper through a gear re-

duction train also drives pointer and counter through the same gear mechanism.

There are four such indicators on the "880" flight engineer's panel, one each for No. 1, No. 2, No. 3, and No. 4 pairs of main and replenishing tanks. Each indicator unit includes its bridge calibrator and amplifier. A three-position switch, just above the bank of indicators, permits reading quantity in main tanks, replenish tanks, or the totals in both. Normally the switch is in TOTAL position. At MAIN position, the switch substitutes an empty-tank capacitance for the actual replenishing tank capacitance, and vice versa.

The flight engineer's indicators in the "600" are governed by a four-position switch; the extra position is for the anti-shock bodies. A fifth gage is added for the center section fuel cells.

The indicator unit includes a second potentiometer, operated by the rebalancing motor. Output from this potentiometer goes to the totalizer circuit. Wing refuel panel repeaters are operated from the rebalancing potentiometer.

In the "880" and in some versions of the "600," a totalizer indicator is at the lower left corner of the center instrument panel. Signals from the separate tank indicators are added in a summation bridge assembly, housed within the indicator. Repeater gages for the "880" are on refuel panels on outboard side of inboard pylons, and duplicate exactly the TOTAL readings on the flight engineer's panel.

"Full" and "empty" adjustments are provided at each instrument. The repeaters require "full" adjustment only.

COMPENSATOR CIRCUIT

The dielectric constant of petroleum fuels is to some degree a function of density. Capacitance gaging systems tend to be self-compensating for variation in temperature or relative densities of fuels; in general, the more dense the fuel, the higher will be the gage reading. Different lots of the same type of fuel, however, may vary in basic electrical characteristics.

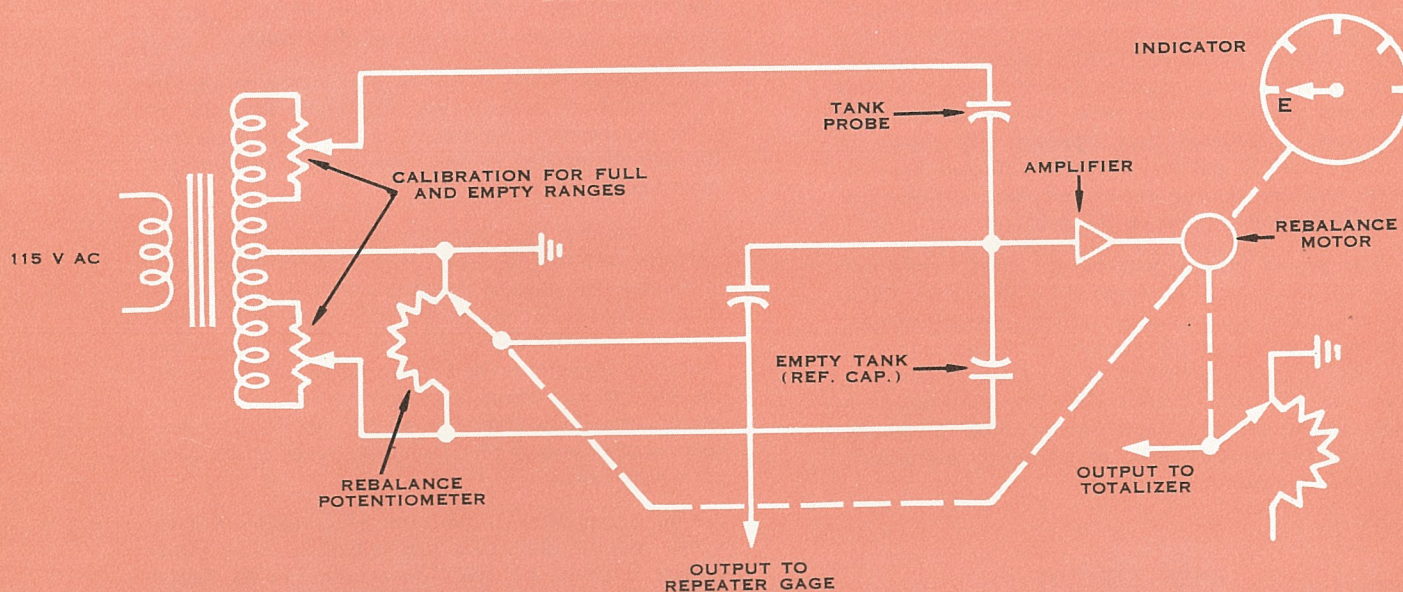
To reduce the error caused by varying characteristics of fuels, comparatively simple compensators are added in the 880/600 gaging systems. These are wire-wound capacitors, termed "monitors," mounted at the low level in each tank.

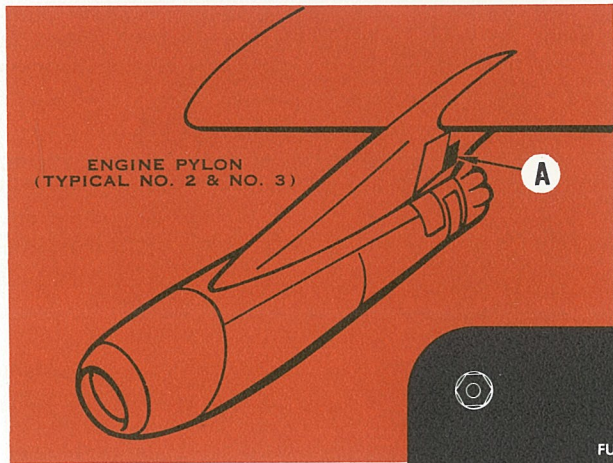
The monitor signal is inserted into the indicator inductive balance circuitry on the opposite side of the bridge from the probe signal. If the dielectric constant of a particular fuel is high, for example, the augmented probe signal would tend to cause a high quantity reading; but the opposing monitor signal will attenuate the probe signal, so that quantity readings will be virtually unaffected, within the range of dielectric constants of standard JP-4 fuels.

PYLON REFUEL SELECTION

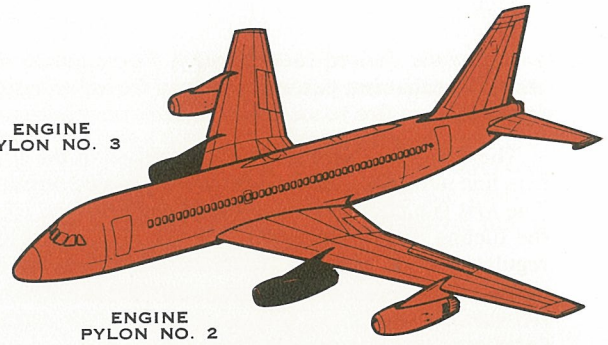
Each refuel panel, pylon-mounted in the "880" and near the wingtip on the "600," has two repeater indicators, one for each of the two pairs of main-replenish tanks in that wing. Around the periphery of each dial is a pointer that can be set to stop refueling when

BRIDGE CIRCUIT - EMPTY TANK



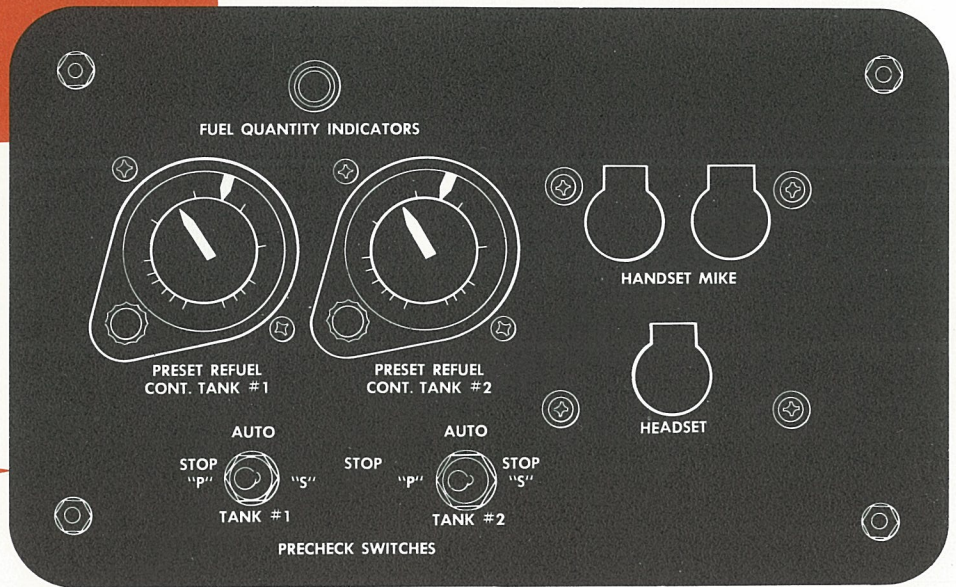


ENGINE
PYLON NO. 3

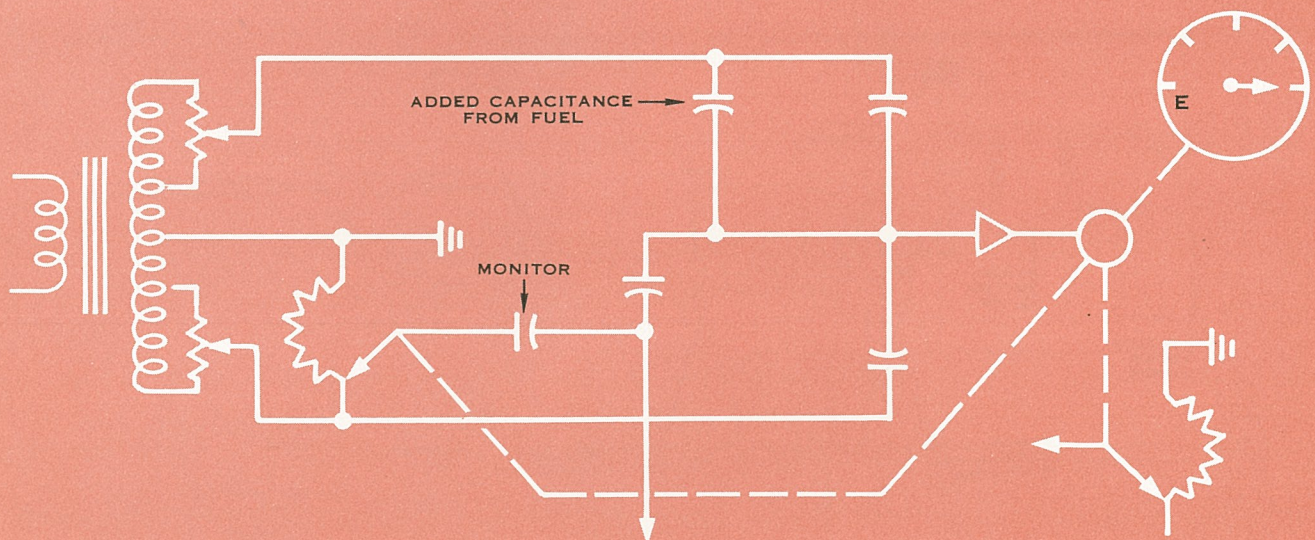


REFUELING CONTROL PANEL
(TYPICAL PYLONS NO. 2 & NO. 3)

A



BRIDGE CIRCUIT - FULL TANK



preset to the desired fuel quantity. Operation of this shutoff mechanism can be traced in the valve system schematic.

There are four successive cutoff valves in the pressure line inlet, each springloaded to the closed position. The first is a check valve, automatically opened when the fueling line is connected. The fourth is a pressure regulator valve, opened by refueling pressure but designed to cut off flow, if pumping pressure is excessive. Between these two is a pair of shutoff valves, termed "primary" and "secondary."

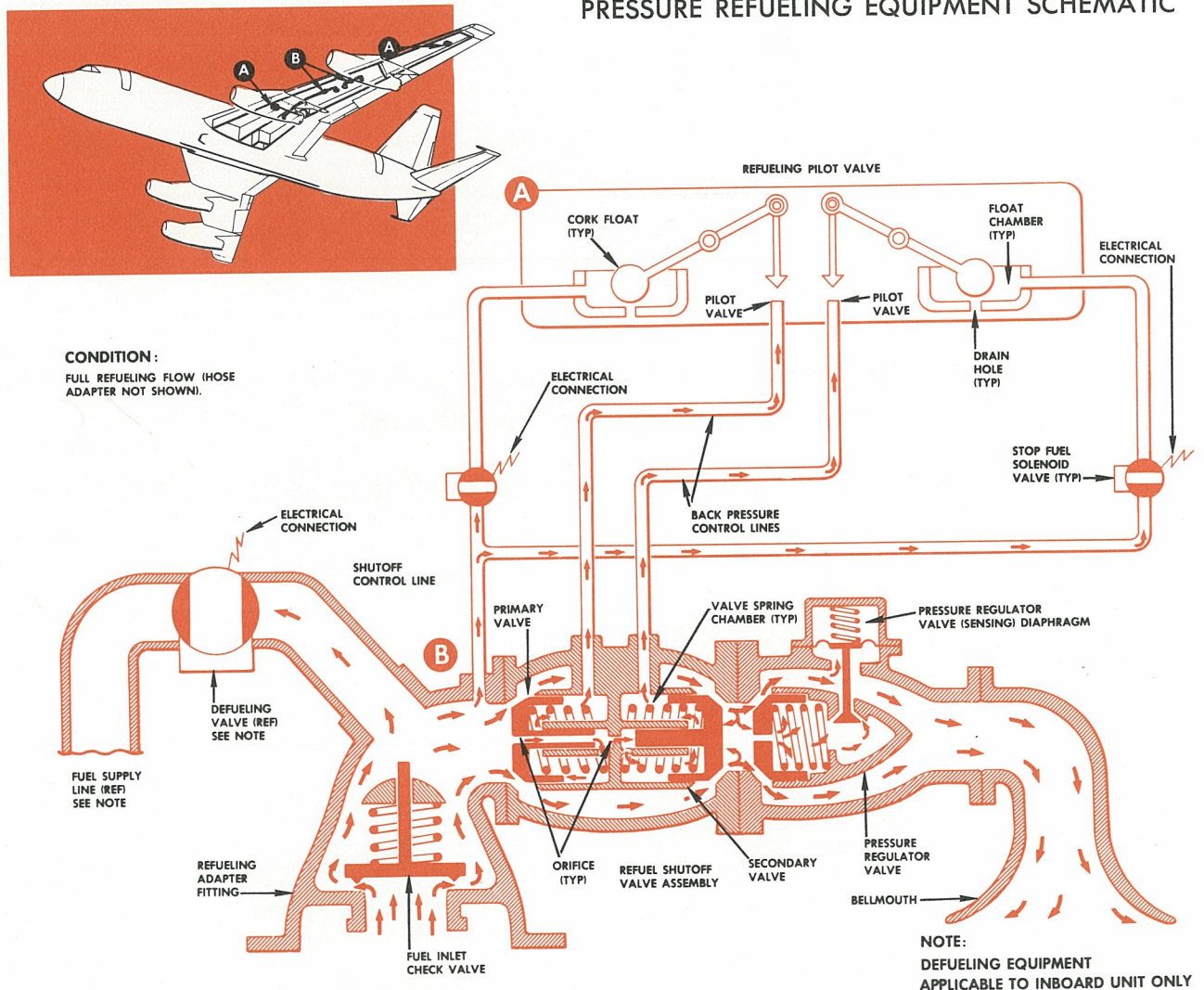
Fueling pressure is 50 psig. When pressure is directed against the faces of the primary and secondary poppets, they open and remain open as long as flow pressure on the face is greater than that inside the valve spring chambers. Bleed orifices through the poppets allow constant flow through the spring chambers and through tubing into overflow pilot valves.

The pilot valves are float-operated. The float chambers are connected via solenoid-operated valves to inlet pressure. The solenoids are connected to pointers on the indicator pointer shaft.

While the fuel flows, the solenoid valves are closed. When the indicator contacts close, both primary and secondary valves open the lines to the float chambers. The floats close the pilot overflow valves, and pressures equalize at the poppets. The spring-loading then forces both valves closed, and fuel flow ceases.

Beneath the indicators on the panel is a test switch marked "P" and "S," for primary and secondary shutoff valves. When refueling, the crewman should test both shutoffs as soon as flow starts. Drains in the float chambers will empty the chambers again in time for the automatic shutoff system to operate.

PRESSURE REFUELING EQUIPMENT SCHEMATIC



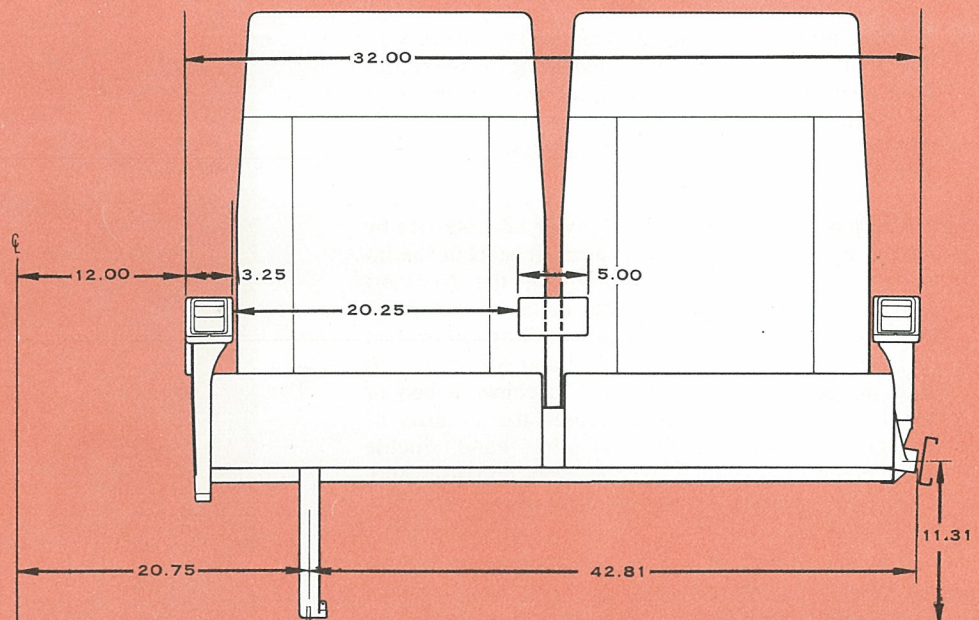
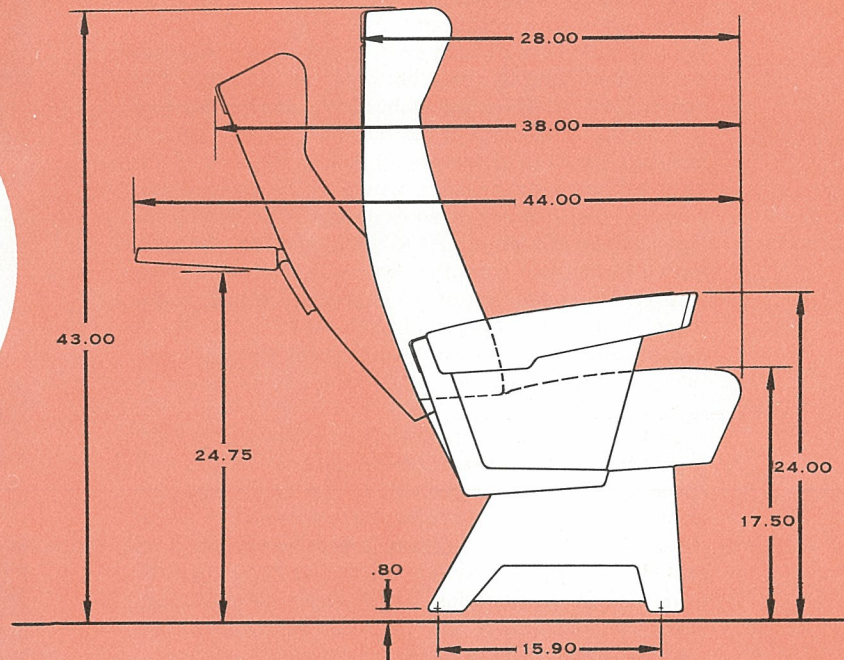
Convair 880/600 Passenger Seating

Passengers traveling on the Convair 880 and 600 jet airliners will settle comfortably into soft contoured seats and relax in an atmosphere of soft music and soft colors. From the luxurious appointments to the sturdy construction, the passenger seats on these advanced airliners were carefully designed to offer the Convair passenger a safe and pleasant trip and deliver him to his destination relaxed and refreshed.

Convair is no newcomer to the art of seating passengers. In almost 15 years of producing such famous airliners as the "240," "340," and "440," Convair has



SEAT DIMENSIONS



acquired a vast store of knowledge and experience in the comfort and safety of passengers.

Beginning with the "240" passenger seats, Convair has pioneered the use of ductile sheet metal construction as a safety measure against impact. For this built-in safety feature, Convair received recognition from the Aviation Crash Injury Research (AvCIR) of Cornell University.

Custom-designed "880/600" seats are classic examples of safe, functional design. As an extra margin of safety, the seat attachment fittings are "built into" the extra strong fuselage and floor structure.

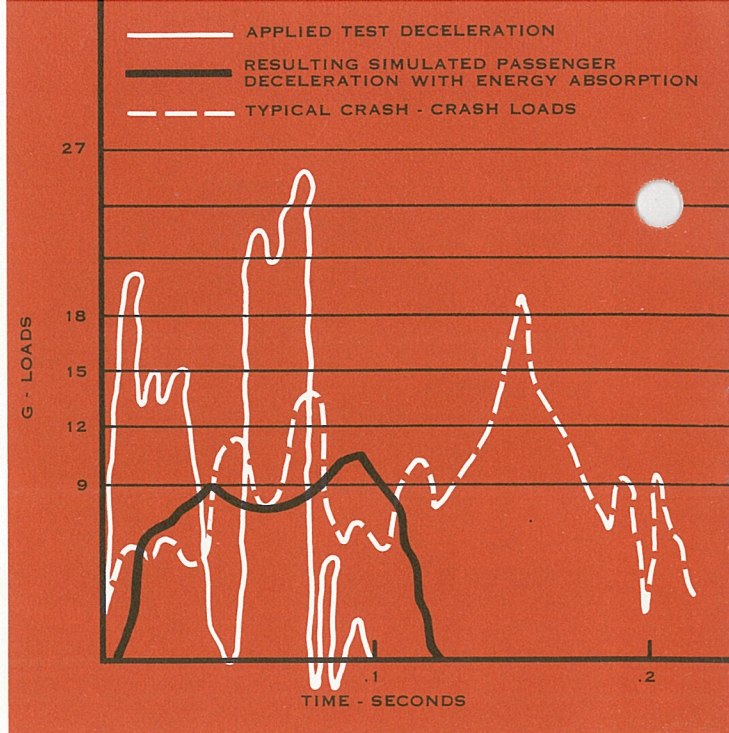
In the first class arrangement, the "880" and "600" have four-across seating in the passenger cabins, two on each side of a 24-inch central aisle. Each seat has a 20¼-inch seating space between the armrests. The center armrest, which is 5 inches wide, can be removed to provide a clear area, if desired. The normal distance between the rows of seats is 38 inches. Because of the unique Convair seat design, providing the greatest shin room in the industry, a six-foot man can stretch his legs to their full length. At this seat spacing, the seat-back can be tilted from the vertical in varying degrees to a reclining position of 38 degrees. A touch of the finger swings out integrated trays from the seatback just ahead. The trays are available for dining, cocktails, or for use as desks.

In the coach configuration, there is five-across seating with rows of two seats on one side of the aisle and rows of three seats on the other. The coach seats are only two inches narrower between armrests than are those on the first class version. It is interesting to note that the coach seats on the "880" and "600" are the same size as the first class "440" seats. Construction-wise, the coach seats are the same as the first class seats and embody all of the safety features.

The Convair 600 passenger seats will be attached to tracks running fore and aft, the length of the passenger cabin. The seats will be adjustable in increments of one inch. This feature, which adds greatly to the versatility of the aircraft, will hold conversion time to a minimum.

The passenger seats on the Convair 880/600 are by far the lightest commercial jet aircraft seats in the industry — and the safest. Employing the Convair-proved concept of formed sheet metal construction, the seats are designed to collapse in failing rather than to break apart. A "breaking" tubular structure (as used in most conventional seats) becomes a bed of lethal spears, and greatly increases the hazards of emergency conditions. On the other hand, ductile sheet metal construction progressively collapses and, while doing so, acts as a very efficient energy absorber.

The importance of energy absorption has become paramount in passenger safety. Convair has developed an energy absorber that works in conjunction with passenger seat belts. The unit, fastened to each safety



PASSENGER SEAT ENERGY LOADS



belt between the strap and the seat base structure, moves when a force of 700 to 800 pounds is exerted on it. To survive high-impact landings, the passengers must be held in their seats, and the seats must remain attached to the aircraft. It was learned that, by the use of energy absorption, it is possible to limit peak decelerations of passengers by decelerating them over a slightly longer period of time. The load transmitted to the seats remains below the seat failure point until the energy absorber travel is exhausted.

Among the many tests that were performed on the Convair 880/600 passenger seating, the dynamic tests proved of special interest.

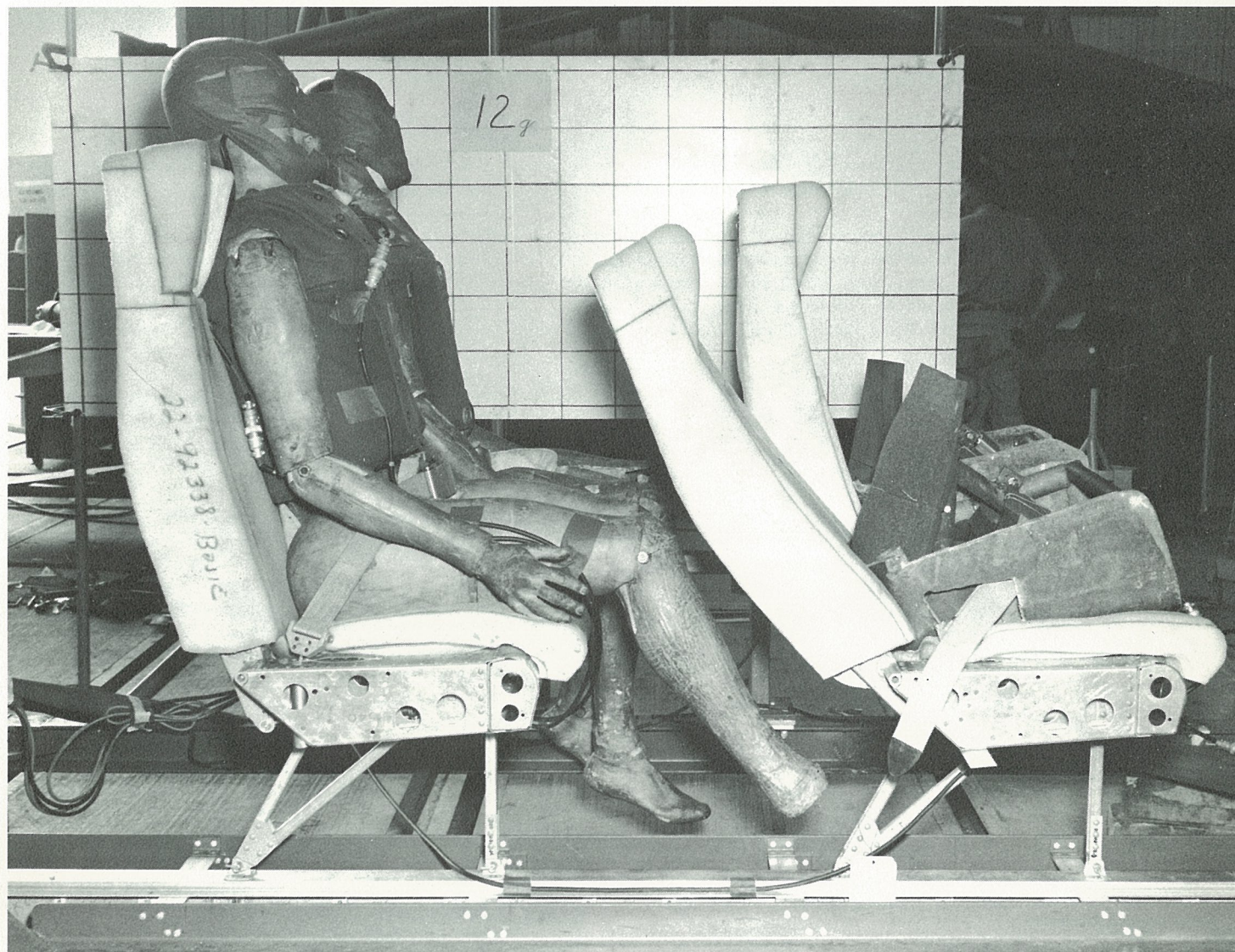
To simulate high-impact landings, the dynamic tests were set up with production-type seats containing 170-pound articulating dummies. The test unit took the form of a giant swing that was released from varying heights. In each test, the swing was stopped abruptly

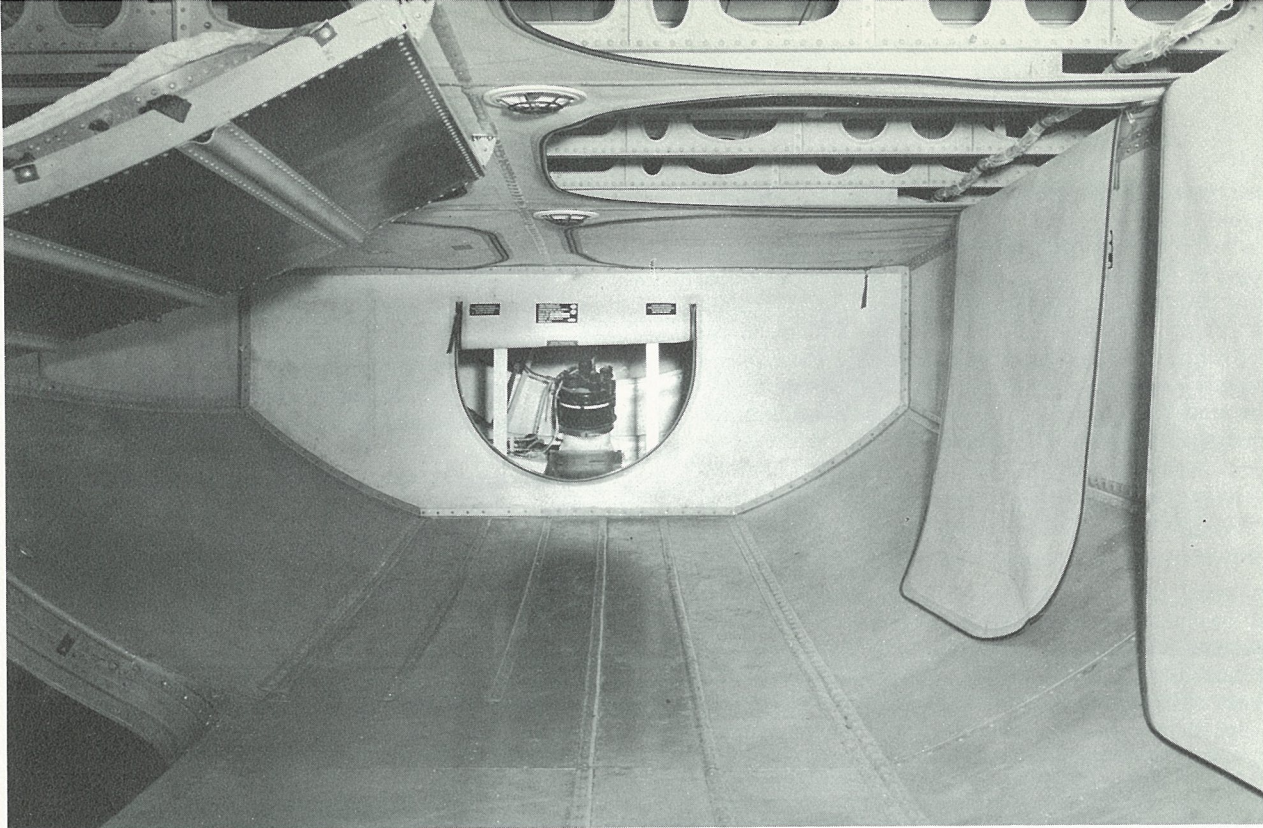
with restraining straps; the forward deceleration and associated data were recorded on magnetic tape.

Tests, with and without energy absorbers attached to the seat belts, were conducted under varying g-loadings. Without the energy absorbers, the seats collapsed; with the energy absorbers the seats stayed erect — the energy absorbers taking the initial impact. In no case did the seats break loose.

The legal requirement for an airplane passenger seat is that it withstand a forward force of 9 g's. Preliminary tests have proved that the Convair-developed seats for the "880" and "600" will not break loose, even when subjected to a force of approximately 15 g's.

Tests are continuing in the dynamic range of 16 to 26 g's. The Convair 880/600 will not only be the fastest, but also the safest jet airliners in operation.





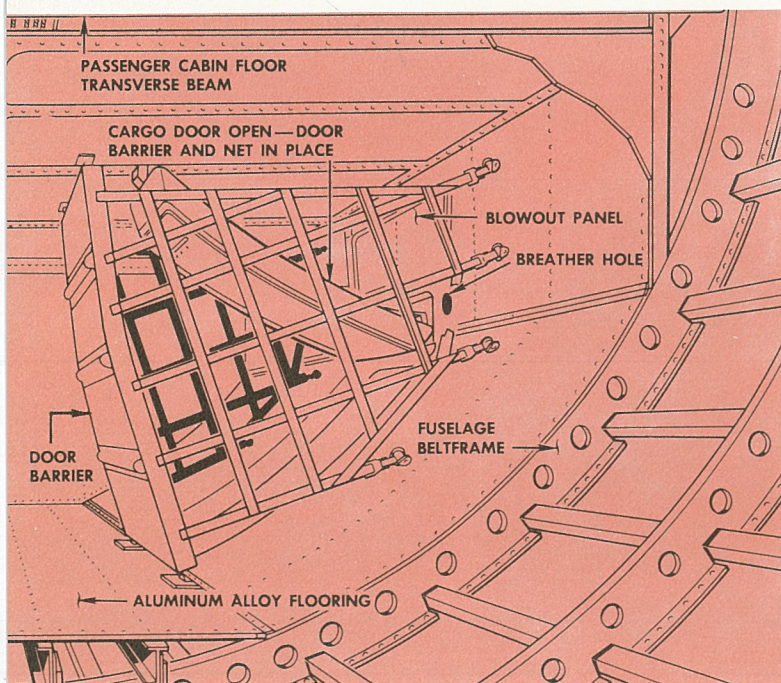
Convair 880 Cargo Compartments

An outstanding feature of the Convair 880 jet airliner is its ability to hold servicing and turnaround times to a minimum during airport stops. One important aspect of this expeditious ground operation is the accessibility of the two cargo compartments, and the ease and speed with which these areas can be loaded and unloaded. The forward cargo area has a capacity of 448 cubic feet; the aft cargo area, 415 cubic feet.

Both the forward and aft cargo compartment floors are less than five feet from ground level, and each is accessible through a large door (approximately 34 inches by 39 inches) that opens inward and upward. The forward area is located between fuselage stations 375 and 603, and the aft area is between fuselage stations 1002 and 1230. The door for the forward compartment is forward of the wing at fuselage station 489, and the aft door is aft of the wing at fuselage station 1116. Both doors are on the lower right-hand side of the fuselage and are held in the closed position by bayonet-type latches. Lights in the pilots' compartment indicate the latched or unlatched position of the cargo compartment doors.

Each door is provided with a door hold-open mechanism consisting of a spring-loaded hook, attached to the lower inside edge of the door, and a cam on the lower end of the bayonet latch actuating shaft. When the door is raised, the spring-loaded hold-open hook engages a pin in the top of the cargo compartment. The door control handle may be pushed back into its recess without releasing the door hold-open mechanism. To unhook the door hold-open mechanism, the door control handle is rotated outward from its recess. This causes the cam on the bayonet latch actuating shaft to rotate and actuate the hold-open hook. The hold-open hook then releases and simultaneously the bayonet latch pins are pulled in, allowing the door to be lowered into the closed position.

Each cargo compartment is provided with several flush-mounted lights in the compartment ceiling that are illuminated by the action of a microswitch when the compartment door is opened. A protective grill



over each lighting fixture prevents luggage or cargo from becoming scorched, if placed close by. A small light at the top, and just inside, of each cargo door opening, also illuminates by action of the door micro-switch. Lights are arranged so as to illuminate the compartment, the doorway, and approximately 18 square feet of ground area near the door.

The ceiling, ends, and inboard sides of the cargo compartments are lined with heavy-duty neoprene-coated fibreglas cloth curtains that are held in place by attach strips and screws. These curtains can be unzipped for access to adjacent structure, and for maintenance of control cables, electric and electronic harnesses, and hydraulic tubes that extend through the lower part of the airplane fuselage.

To prevent shifting cargo from blocking the entrance to the cargo compartments, each opening is equipped with a fibreglas barricade that hinges from the compartment ceiling and snaps into place by spring-loaded pins that seat into the compartment floor just inboard of the door opening. To open, the barricade swings up and outward and hooks to the edge of the open compartment door.

The barricade is equipped with nylon webbing at the sides of each compartment door opening to further prevent cargo from blocking the entrance.

The floors of the cargo compartments are constructed of 0.045 inch thick aluminum, and are capable of withstanding static loads of 100 pounds per square

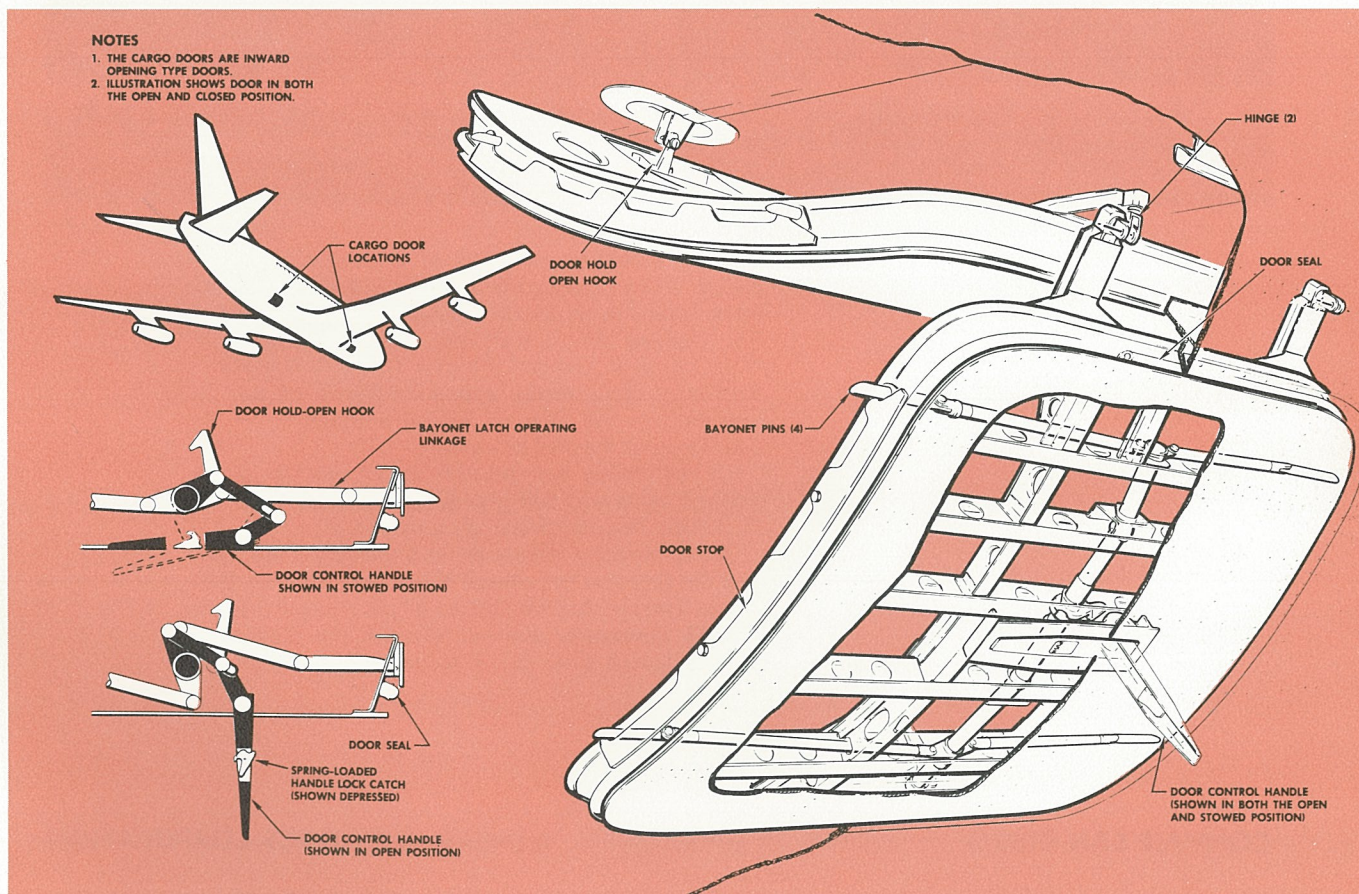
foot or 20 pounds per cubic foot. Nylon skid rails, extending fore and aft, are attached to the surface of the compartment floors. The floors are insulated from direct contact with the outside structure of the air-plane by fibreglas angle supports.

The Convair 880 cargo compartments are heated indirectly by circulating air that passes between the compartment lining and the adjacent insulated structure. The compartment temperature is kept above 32° F to prevent cargo from freezing.

To comply with "FAA Defined" Class D requirements, the air inside the cargo compartments is static, except for breather provisions between the cargo compartment and the passenger cabin. This is accomplished by a small circular opening 2.75 inches in diameter, connecting the compartment with the cabin. Should combustion occur in a compartment, the static air condition would prevent the fire from spreading. As soon as the existing oxygen is consumed, the fire would be smothered.

The "880" cargo compartments are completely pressurized, an important requirement for the high altitudes the jet airliner will be flying. As with the passenger cabin, the cargo compartments maintain a pressure environment equivalent to 8,000 feet altitude. This feature protects delicate cargo, and eliminates the embarrassing aftermath of broken cosmetic containers and leaky fountain pens left to the mercy of extreme altitude pressure changes.

14 53



A Convair 880, the fastest commercial jet transport in aviation history, took off from San Diego's Lindbergh Field (California) at 10:11:46 A.M., February 10, 1960, and arrived at Miami's International Airport (Florida) 3 hours, 31 minutes, and 54 seconds later, after spanning the North American continent, to establish a transcontinental speed record for commercial jet transports.

Flown by a Delta Air Lines crew, the gleaming white, blue, and red Convair 880 jet airliner, christened the "Delta Queen," carried 34 distinguished passengers on its record-breaking flight. Among those aboard were officials of Delta, Convair, General Electric Co., and the Civil Aeronautics Board.



C. E. Woolman, president of Delta Air Lines, declared, "The Convair 880 opens a new era of swifter, more luxurious air travel for America and the world. The Convair 880 is truly the aristocrat of jets . . . With its great General Electric CJ805-3 engines — delivering more thrust pound-for-pound of any jet ever built — the Convair 880 is destined to be the pace setter of the civil airways.

"It will bring new prestige to an already distinguished name and will greatly advance United States leadership in commercial air transportation."

An outstanding tribute to the Convair performance was the fact that the official Flight Plan filed an Estimated Time of Arrival (ETA) which allowed 3 hours and 32 minutes of elapsed time for the flight. The actual elapsed time cut 6 seconds from the Flight Plan ETA.

CONVAIR SAN DIEGO

CONVAIR DIVISION

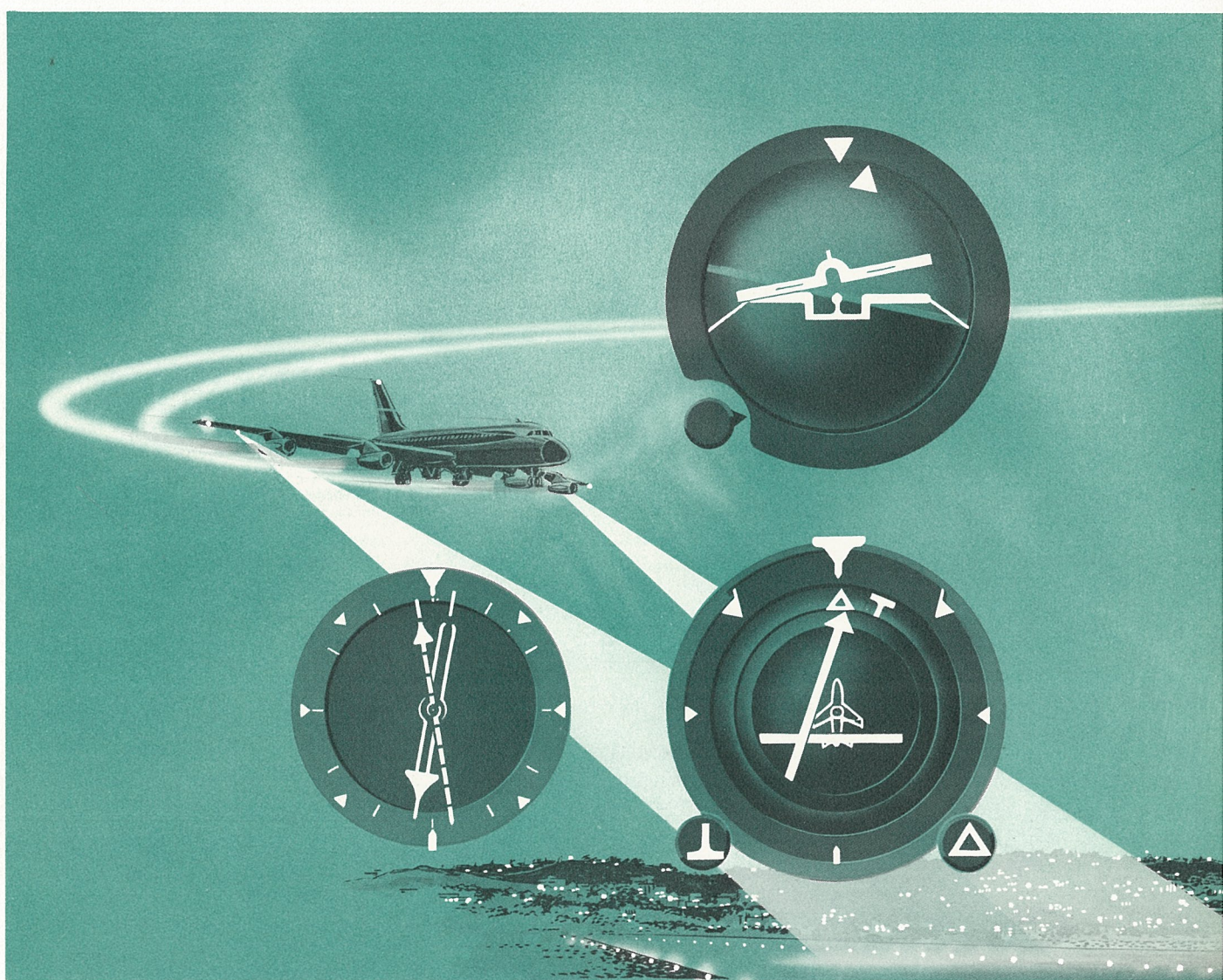
GENERAL DYNAMICS CORPORATION

VOLUME XI

NUMBER 11

MARCH 1960

Convair *Traveler*



In this Issue: Convair 880 Flight Director and Autopilot Systems

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OUR COVER

These three small instruments in the "880" flight compartment not only tell the pilot where he is and how to fly where he wants to go; they even tell the airplane how to fly itself there. Bob Sherman is the artist.

Convair Traveler

VOLUME XI NUMBER 11 MARCH 1960

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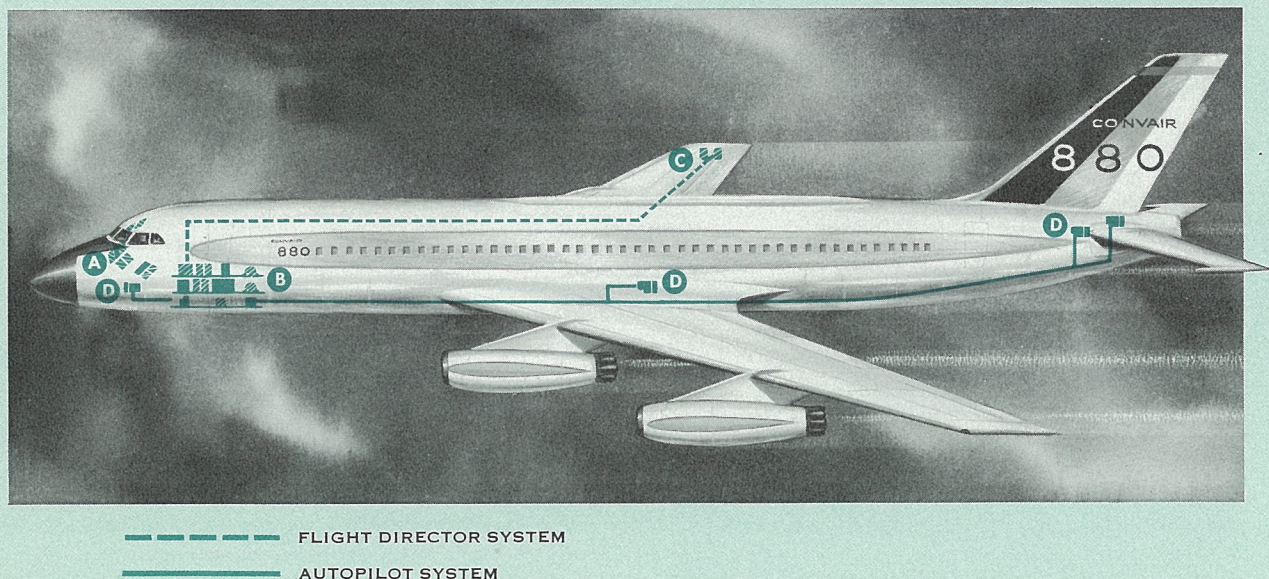
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Convair 880 Flight Director & Autopilot Systems

Bendix Compass System, Series 300 Flight Director, and PB-20 Autopilot



Flight Director and Autopilot Systems comprise (A) instruments and controls, (B) electronic compartment components, (C) compass flux gate sensors, and (D) control surface servo motors.

It is not yet quite practical to build an airplane in which the pilot can dial "Chicago" on his control panel and then sit by while the airplane takes off and proceeds to destination. Still, the designers have come a long way towards this end, and they are obviously going farther. When a pilot first steps into the cockpit of his brand new jet airliner, he may find provisions on his panels for equipment to be installed when facilities are ready, or even for devices still being developed.

At the other extreme, the tried-and-true cannot be dispensed with. Though he may never use it, the pilot will find on his 1960-model instrument panel the oldest of navigational aids, a plain magnetic compass; and another instrument as basic to flight as a binnacle to a ship at sea, the ball turn-and-bank indicator.

Between the old and the not-yet-perfected is the equipment with which the pilot will do most of his flying. In the Convair 880 and 600 jet transports, he will have the best available.

The pilot will be able to set up instructions on his panels for his airplane to fly at a certain altitude in a certain direction, and then sit back and watch it fly the exact heading for hours, if he so desires. He can couple his autopilot to an omnirange radial beam and let it find the radial; work out the wind correction; and follow the beam to and over the station, and on away from it until an instrument flag warns him that the beam has faded out.

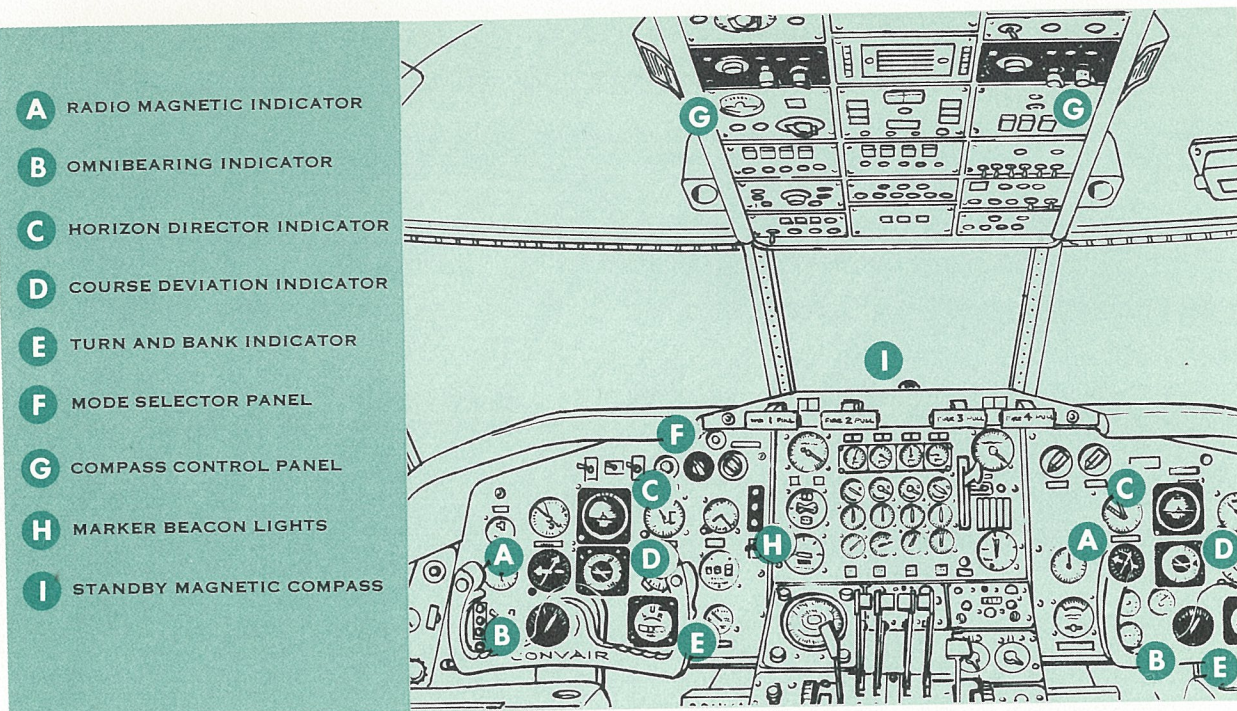
Landing, he can tune his radio to an ILS station and sit by while the airplane finds the center of the beam and glide path, and follows the path down to a few feet from the runway.

Instruments give him a continuous report on his bearings, relative to compass and/or the radio beams in which he is interested. They give him the flight attitude of his airplane and, in some installations, specific instructions on how to fly or intercept a desired course, detailed to the point of telling him at what angle he should be banking.

Much of this instrumentation and automation represents recent development in equipment, generally familiar to most pilots today. Radio direction-finding, for example, dates from the 1920's, and the two-needle radio magnetic indicator is now standard equipment. Automatic pitch and yaw control was developed to a high degree of effectiveness during World War II. Some automatic pilots in recent years have provided straight and level flight, turn coordination, altitude control, and glide path lock-on.

What is new in today's jet airliners is, first, the concentration of navigational information in instrument display; second, the refinement in precision of control; and, third, the extent of automation possible.

Either of two flight director and autopilot systems are installed on "880" and "600" aircraft: the Bendix Polar Path compass system, instrumentation, and PB-20G autopilot in "880" Model 22-1; and the



Pilots' flight director instruments and control panels.

Sperry Gyrosyn compass, instrumentation, and SP-30 autopilot in "880" Model 22-2 and "600" Models 30-5 and 30-13.

The two systems provide approximately the same instrument information and autopilot operation, but there are differences in operational details and instrument displays. Because most readers will be interested in one or the other system, the Traveler will take them up separately. This issue is concerned primarily with the Bendix (Eclipse-Pioneer) instruments and autopilot. The Sperry systems will be discussed in a future issue.

Flight Director System

"880" MODEL 22-1

Compass, radio, and airplane attitude information is provided for both navigation instruments and autopilot. Since part of autopilot control is provided via the instruments, it may be well to examine them first.

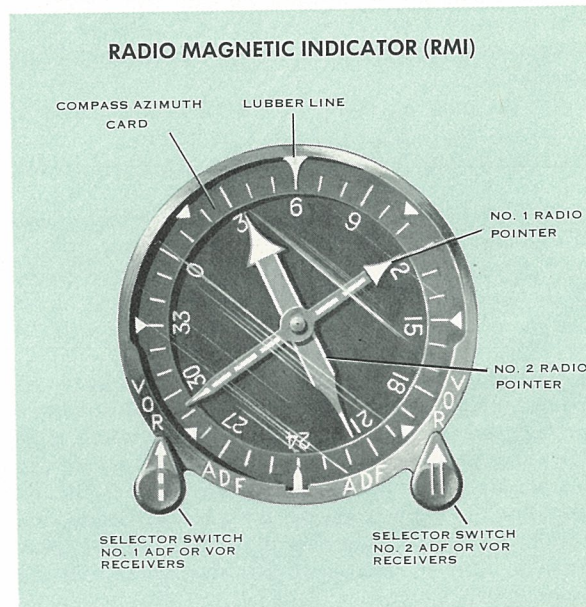
Familiar instruments on the "880" Model 22-1 pilot's and copilot's panels will include the turn-and-bank indicator, omni-bearing indicator (OBI), radio magnetic indicator (RMI), and marker beacon indicator lights. The turn-and-bank is lower right on each pilot's panel; the OBI, showing bearing of the VOR station tuned in, is lower left. Marker beacon lights are upper right. A single standby magnetic compass is mounted above the center panel.

The RMI is similar to that in the Convair-Liners, with some capabilities added. The RMI now operates with either standard broadcast or VHF radio signals. The two needles can respond to the two ADF re-

ceivers, to the two VHF navigation receivers, or to one of each. The compass card is part of the compass system.

In the center of the panel are the two principal flight director instruments. The upper is the horizon director indicator; the lower is the course deviation indicator.

The horizon director has command functions, governed by a flight selector mode switch located above and to the right of the dial. When the flight



steering computer is not in use — mode selector switch in OFF position — the indicator serves as a conventional vertical-gyro-controlled artificial horizon. It shows an attitude sphere, the upper half light blue and the lower half black, with an airplane reference line at dial center. A pitch trim knob in the lower left corner trims the sphere within a range of 11° up to 6° down, to establish a nose-up or nose-down flight attitude if desired. At the top of the sphere is a pointer that moves against reference markings on the indicator face to indicate roll angle. Markings are at 10° , 20° , 30° , and 45° .

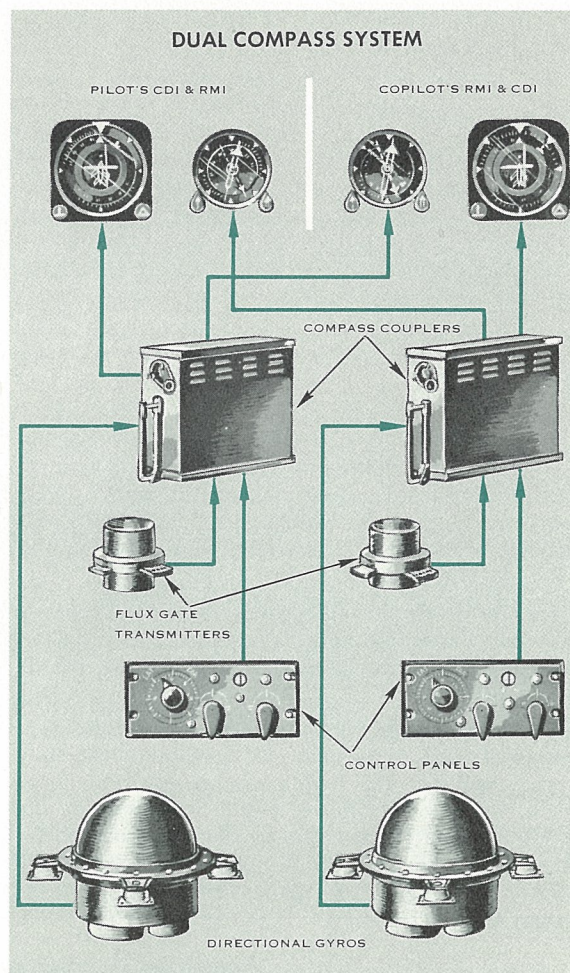
The course deviation indicator (CDI) combines in one instrument compass heading, omni-bearing selection, localizer or VOR beam indication, VOR to-from indication, glide slope indication, and radio warning and compass power failure flags. It also provides course and heading settings for manual or autopilot operation.

This is quite a bit of information and function for one four-inch-square instrument. The CDI, however, bears enough resemblance to other flight instruments in current use that pilots have less difficulty than the layman might suppose, once they have familiarized themselves with the dial patterns.

In essence, the CDI face shows airplane compass heading and position relative to selected VOR or ILS beams. These indications are independent of the flight steering computer and of the autopilot. The compass information and its sources may be examined first, and then the indications in VOR and ILS navigation.

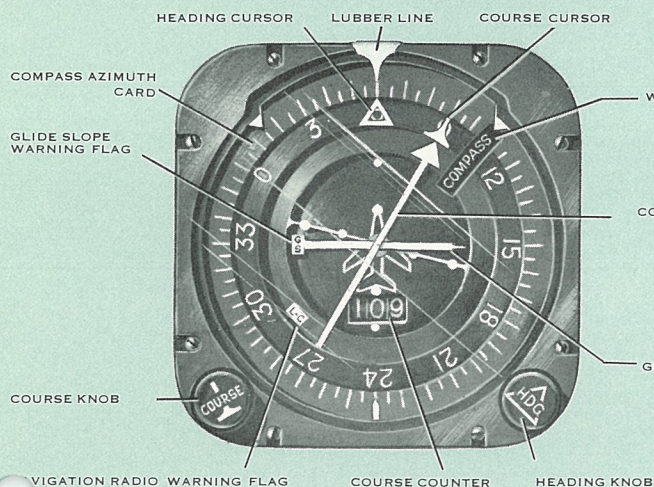
POLAR PATH COMPASS SYSTEM

The compass heading is the primary frame of reference. The CDI azimuth card, on the outer rim of the dial, is a replica of that on the RMI, controlled

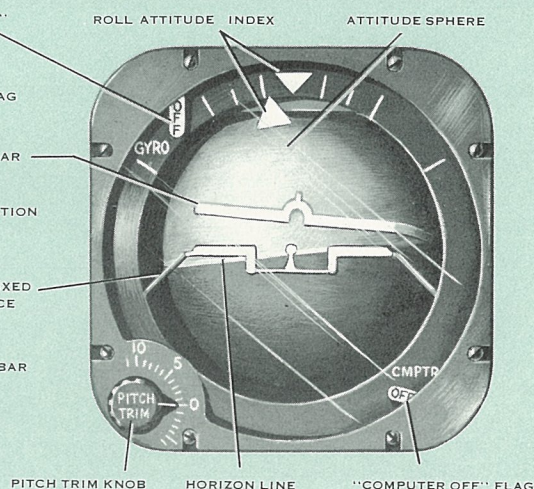


Each of the two complete compass systems govern indications on pilot's and copilot's instruments.

COURSE DEVIATION INDICATOR (CDI)



HORIZON DIRECTOR INDICATOR (HDI)



by the same compass systems. Airplane heading is under the lubber line at the top.

The Bendix Polar Path compass system is the remote-magnetic gyro-controlled type. Where magnetic readings are stable, at middle and lower latitudes, the gyro can be slaved to the earth's magnetic field. This is sensed by a flux gate transmitter in the right wing tip. A special knob setting allows rapid slaving of the compass card to the flux gate transmission.

Over long distances, the slaved mode is usually more reliable. Directional gyro control, under gyroscopic direction only, is very accurate for short-term reference, and is essential for flight at high latitudes where magnetic indications are unreliable. Since gyro drift caused by rotation of the earth is greatest near the poles, a special device has been added to compensate for the apparent drift. This is set by a latitude correction dial on the compass control panel (overhead). Random drift, caused by friction and other such inescapable factors, is held to a maximum of $1\frac{1}{2}^\circ$ in 30 minutes.

The resolving unit for signals from the flux gate compass and directional gyro is the compass coupler. Its output goes to the RMI, CDI, and to the autopilot.

There are two complete compass systems—two flux gates, two gyros, two couplers and control panels. Output of one is to the pilot's CDI, output of the other to the copilot's. The RMI's are criss-crossed, so to speak; the pilot's compass system operates the copilot's RMI and vice versa, so that each has on his panel indications from both systems and, hence, will quickly notice any discrepancy caused by compass system malfunction.

COURSE DEVIATION INDICATOR & HORIZON INDICATOR

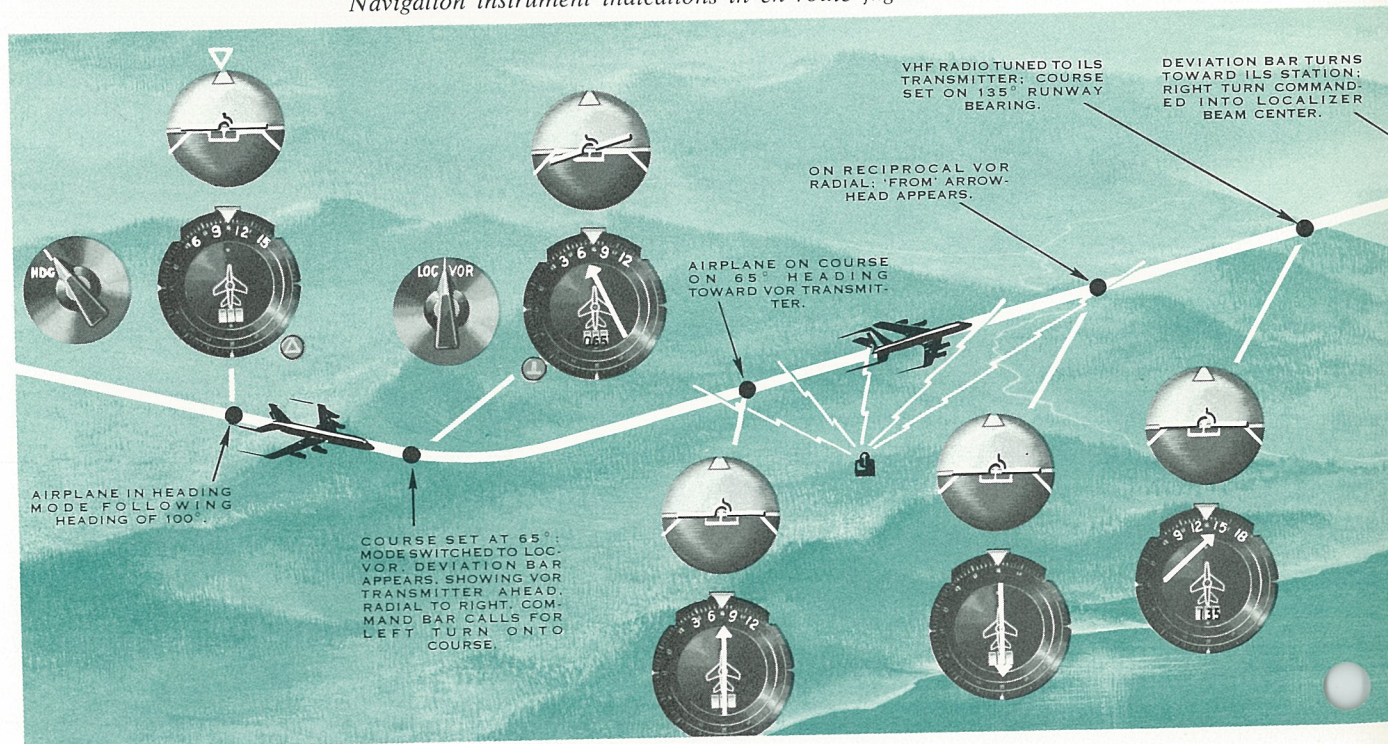
Inside the CDI azimuth card is the radio beam information. To follow a VOR radial, the pilot—or copilot—tunes in his VHF radio to the selected station and sets into his CDI the radial he wishes to follow. This he does by turning the **COURSE** knob on the lower left corner of the instrument. The knob positions an inverted T on the azimuth card, and also turns a counter in the lower half of the dial. At a 30° selected course, for example, the T will be at the figure 30; the counter will show 030; and the lubber line at the top will show actual heading of the airplane.

Simultaneously, a deviation bar appears inside the azimuth ring, representing the VOR beam selected. It points along the beam—that is, it shows the beam direction relative to the airplane heading; and it is displaced laterally to show location of the beam relative to airplane location. In the center of the dial is outlined a small airplane symbol for reference. If the radial is ahead to the left of the airplane, crossing the airplane's projected path at 40° angle, for example, the bar will be at 40° from vertical, above and to the left of the symbol.

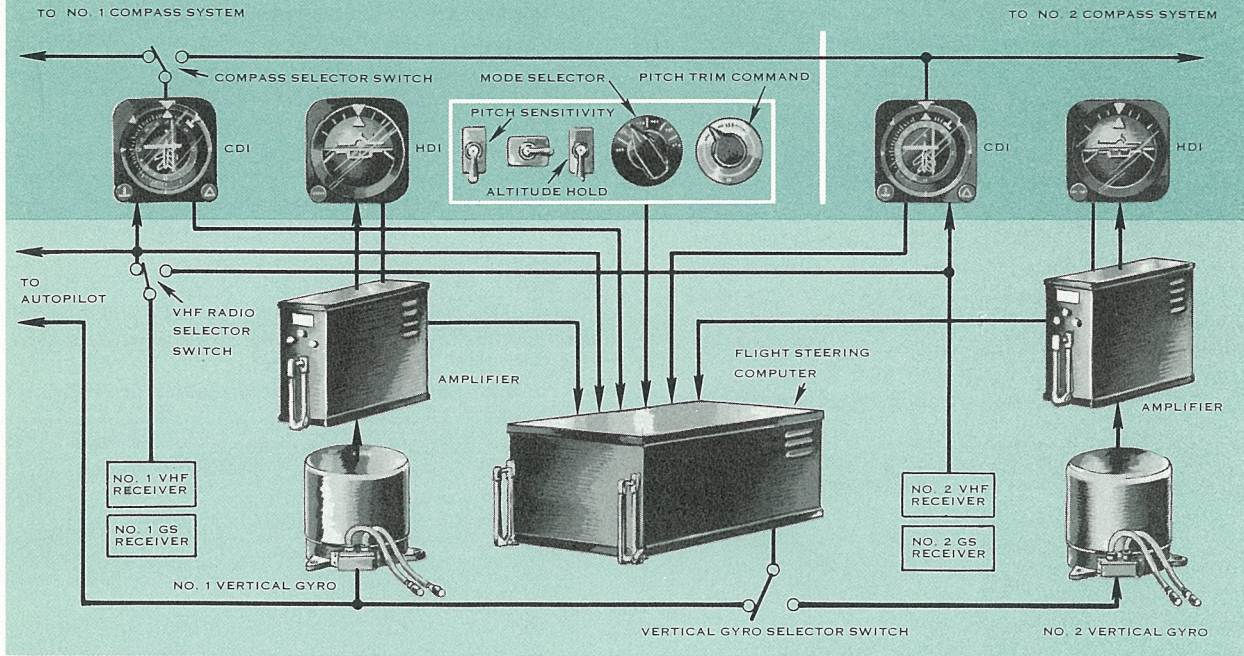
When the VOR station is ahead of the airplane, a triangle appears just inside the inverted T cursor; if the VOR station has been passed, the triangle appears opposite, at 180° from the T.

In ILS operation, the pilot or copilot tunes in the station and sets the localizer inbound runway bearing

Navigation instrument indications in en route flight.



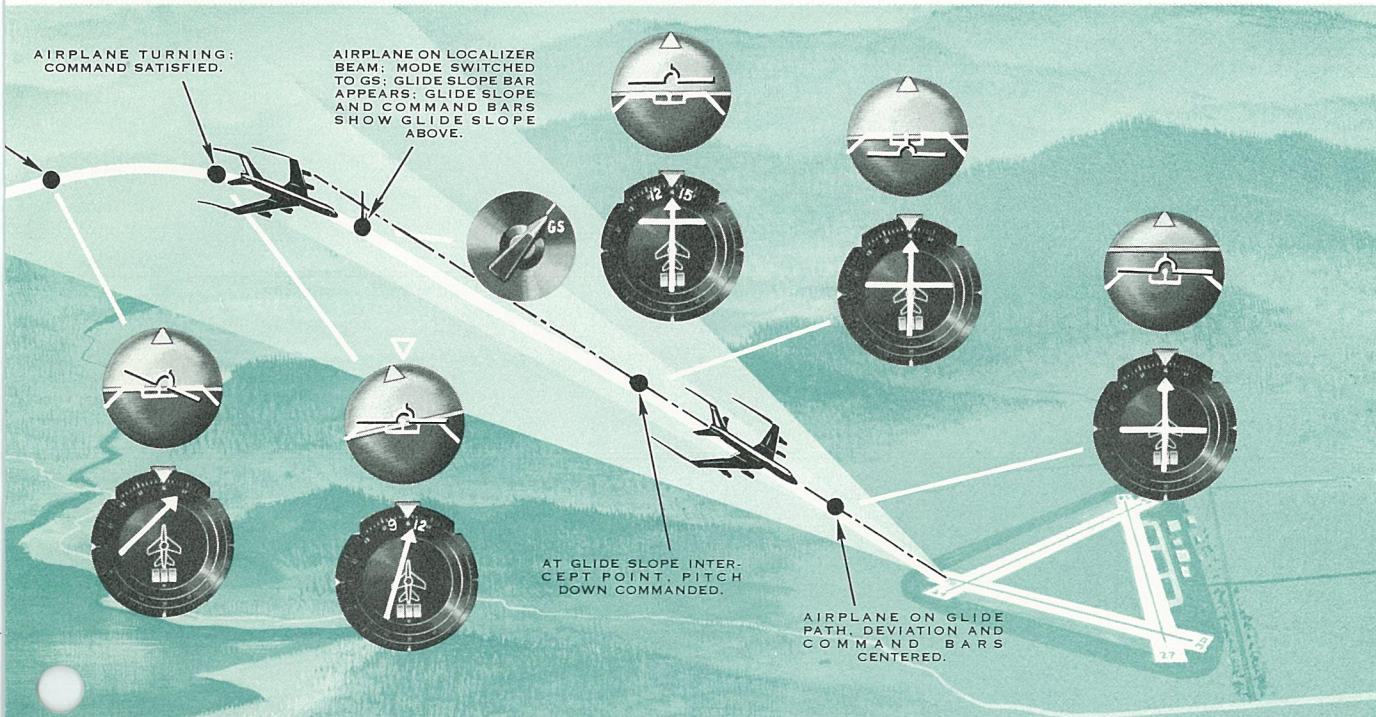
SCHEMATIC — FLIGHT DIRECTOR SYSTEM



into the CDI by the COURSE knob. As with VOR, the deviation bar appears to show the localizer beam direction and location with respect to the airplane. The to-from triangles do not show in connection with a localizer beam.

When an ILS localizer is tuned in, the glide slope receiver is automatically tuned to proper frequency. The glide slope signal adds a second bar on the CDI, a horizontal line, displaced up or down from center to show relative location of the glide slope.

Navigation instrument indications during ILS approach.



FLIGHT DIRECTOR

It may be seen that the CDI, while not a command instrument, can be used to fly a radio beam, by a "follow the needle" technique. The flight director system provides a much more sensitive method of following either a compass course or a radio beam, by adding a command bar, governed by the flight steering computer, to the Horizon Director Indicator.

The mode selector switch beside the horizon indicator has three modes on its dial: heading, localizer-VOR, and glide slope. A fourth mode, altitude hold, is controlled by a separate switch. The pilot may fly these indications in full manual control — by control column and rudder pedals — or by manual manipulation of the autopilot pitch and turn knobs. (Autopilot operation in equivalent modes is explained later herein.)

1. In HDG mode, the pilot, by turning the HDG knob on the lower right-hand corner, sets into the CDI the heading he wishes to follow. The selection is shown on the azimuth scale card by an arrowhead, which turns with the card. The command bar will then indicate what bank angle is required to turn immediately into the selected compass heading. The pilot follows the bar — if the bar slants down to the right, he turns right. By keeping the command bar aligned with the artificial horizon, he will turn and straighten out at the desired heading. If the airplane wanders, the command bar will indicate the corrective action.

2. In VOR-LOC mode, when the pilot sets the selected course into the CDI, the horizon indicator bar will direct a turn bank toward the selected VOR radial, or toward the center of the localizer beam, and will give him continuous instructions on flying to

and along the beam. The computer will automatically develop the required wind correction angle.

3. In GS mode, the glide slope receiver will add its signal, and the command bar will show nose-up, nose-down and/or bank angle required to capture and hold to the glide path.

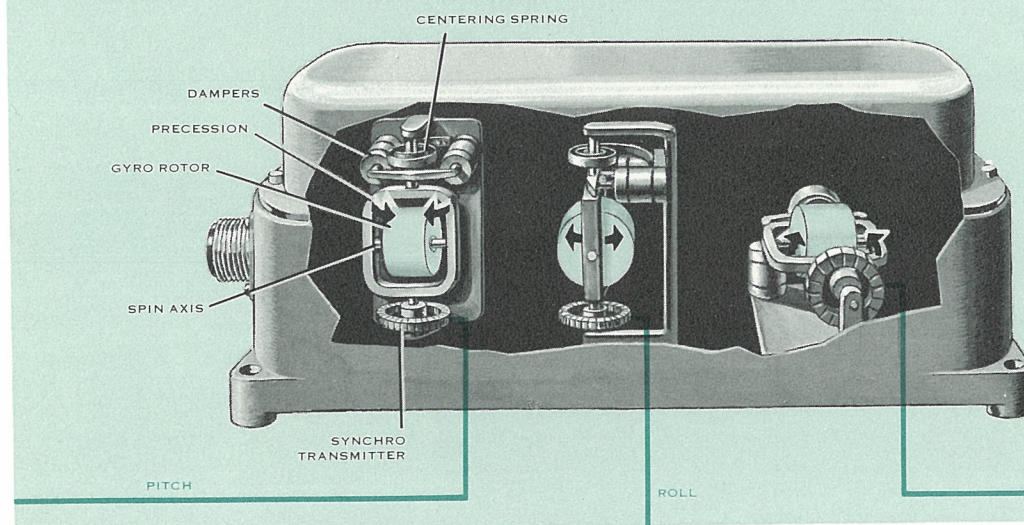
4. Altitude hold mode is engaged by a separate switch on the pilot's instrument panel. With the switch at ON, the horizon command bar is controlled in pitch as a function of altitude. Flying so as to keep the command bar at vertical center will hold the airplane at the altitude at the time of switch engagement.

Extra sensitivity has been added to the "880" horizon director command bar. High and low sensitivity selection can be made by a two-position switch on the pilot's instrument panel.

As has been noted, the horizon indicator reverts to a conventional gyro horizon when the mode selector switch is at OFF. Should the pilot's vertical gyro system malfunction, he can switch to the copilot's system gyro for primary attitude function. The pilot may also, if necessary, select the copilot's compass system for his CDI by means of a transfer switch on his instrument panel. He may switch his CDI to signals from the copilot's VHF or glide slope receivers; however, in such a case, both course settings must be identical.

An emergency operation by radio reference alone is provided in the CDI. The course knob can be pulled out to disengage the compass dial servo, and the whole rotating display can be rotated by the knob until the course deviation bar is perpendicular. This bar will remain under radio control and will indicate the relative displacement of the airplane from the VOR radial or localizer beam center. Under these conditions a red flag will emerge in the lower left corner of the CDI.

SCHEMATIC — AUTOPILOT THREE-AXIS RATE SENSORS



Bendix PB-20 Autopilot

The autopilot is a high-gain, transistorized system. Its basic signals are received (1) from the magnetic, gyroscopic, and radio sources that operate the flight director instruments; (2) from gyroscopic rate sensors in the three axes of the airplane; and (3) from instructions set into the pilot's CDI.

In brief summary of the gyroscopic controls, it may be noted that the vertical and directional gyros, already mentioned in connection with flight instruments, are displacement type; the electrical signal picked off is proportional to amount of gyro displacement, or precession, and hence to amount of change in airplane

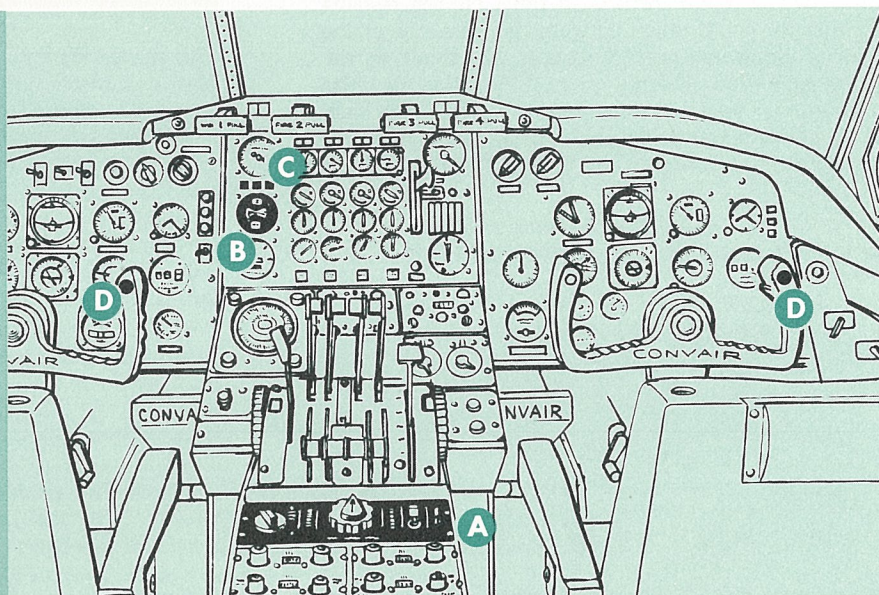
With the switch in AUTOPILOT position, yaw damping is always engaged. There are five autopilot modes available, selected by the multiposition switch at the left end of the panel. A separate altitude hold switch is at the right end of the panel. With the switch in ALT position, in all modes except when locked on glide slope, the airplane will hold level flight at the altitude at which the switch was actuated.

AUTOPILOT MODES

The operation of the autopilot in the five modes is as follows:

1. With the switch at MAN, the airplane holds automatically whatever heading it has at the time of

- A** AUTOPILOT CONTROLS
- B** AUTOPILOT TRIM INDICATOR
- C** AUTOPILOT WARNING LIGHTS
- D** DISENGAGE BUTTON



Autopilot instruments, warning lights, and controls.

attitude. The autopilot sensors are rate gyros; by confining gyro precession to a small range and spring-loading the mounting of the gimbals, the electrical signal picked off is made proportional to rate of airplane attitude change rather than to amount of change. Rate sensors have been found essential for automatic control of high-speed aircraft; control response is quicker and is proportioned to deflecting forces.

The autopilot control panel is mounted on the pedestal between the pilots, accessible to both. At the right on the panel is a switch with three positions, OFF, AUTOPILOT, and DAMPER.

The DAMPER position engages only the yaw damper, which operates in connection with the rudder. Since human reaction time is too slow for consistently stable directional control at high speeds, yaw dampers are currently used in jet aircraft almost all the time after takeoff until landing.

engagement. The autopilot is under control of the compass system, either gyro or magnetic, as determined by the compass control setting.

Changes in heading, however, can be made by the TURN knob in the center of the panel. When the knob is rotated, signals are fed to the aileron control channels and the airplane enters into a smooth turn; it continues to turn until the knob is returned to the center detent. The compass system then resumes control, and the airplane will continue on the new heading.

Pitch angle can be controlled by the pitch wheels, located on each side of the TURN knob. They rotate together to operate the elevator servo, and also the trim servo that moves the horizontal stabilizer. The airplane will nose up or down, and will then maintain whatever pitch angle it holds at the time the wheels are stopped.

The pitch wheel is disconnected by a magnetic clutch when the altitude hold switch is on, or when

glide slope is engaged. In all modes, the stabilizer will be trimmed constantly, to relieve aerodynamic load on the elevator and to unload the elevator servo. When the mode is changed from altitude hold or glide slope to manual, a friction device and holding coil maintain the trim already set into the controller, so that transition to manual control will be smooth.

2. In HDG mode, the pilot sets the heading he wishes into the course deviation indicator by means of the heading knob. Then, when the autopilot mode switch is turned on HDG, the existing compass heading signal is replaced by the preset heading signal, and the airplane will execute a coordinated turn into the heading. If the pilot wishes to change course, he need only turn the HDG knob to the new setting, and the airplane will follow as he turns the knob.

3. In LOC-VOR operation, the pilot, by turning the COURSE knob, presets in the CDI the bearing of either the VOR radial he wants to follow or of the localizer beam of an ILS station. He tunes in the station and then switches to LOC-VOR mode. The autopilot will then make the proper turns to approach the beam asymptotically and will follow the beam, automatically developing the proper wind correction angle.

4. In GS AUTO (glide slope automatic) position of the mode switch, the autopilot will continue to hold

the center of the localizer beam until the glide slope is intercepted. In this mode, interception must be from below. At interception, altitude hold will be automatically disengaged, and the airplane will nose down and follow the glide path.

5. GS MAN (glide slope manual) permits capture of the glide slope under manual control. Whereas automatic glide slope engagement is a recent development, GS MAN provides the pilot essentially the same method of capturing the glide path that he had in most transports of the Convair-Liner generation. He can approach the glide path in LOC-VOR autopilot mode from either below or above, and then switch to GS MAN for lock-on. From this point on, autopilot operation is identical with that in GS AUTO mode.

INTERLOCK & WARNING SYSTEMS

The autopilot mode selector switch is springloaded to MAN position, and is held in other positions by energized solenoids. The TURN knob has a priority in all autopilot modes. When it is rotated more than 5° left or right, microswitches cut off all compass or radio directional signals and deenergize the holding solenoid, so that the switch returns to MAN. Unless the TURN knob is in the center detent, the mode selector switch will not stay in any position but MAN, and the autopilot cannot be turned on.

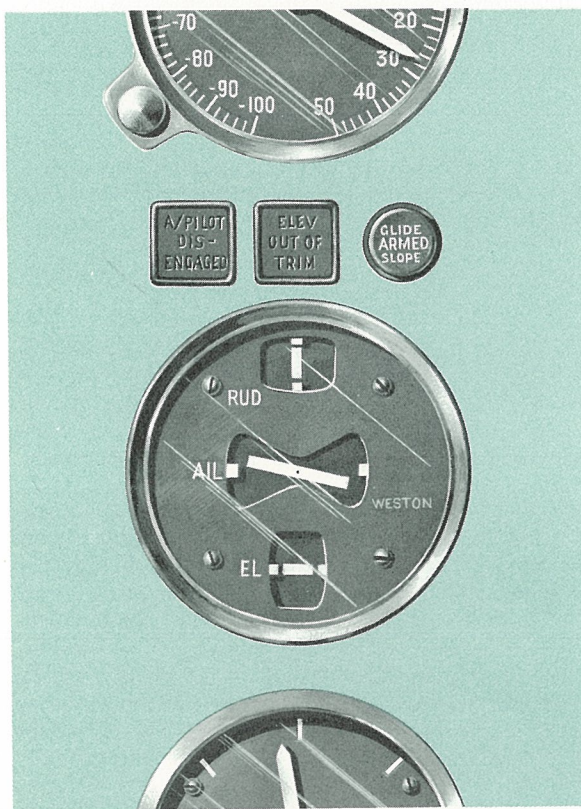
Similarly, the AUTOPILOT-DAMPER and altitude control switches are springloaded to OFF and held in other positions by solenoids. On each pilot control wheel is an autopilot disengage button; when it is depressed, the holding solenoids are deenergized, and autopilot, altitude hold, and yaw damping are all disengaged. The airplane is instantly under full manual control. The yaw damper may be re-engaged after a manual takeover.

Interlock relays in the autopilot system monitor the 115/200-volt electrical supply, and disengage the autopilot by deenergizing the switch solenoids in the event of power failure. A number of other conditions that would prevent satisfactory yaw damping or autopilot operation will cause the interlock circuitry to prevent autopilot engagement.

Near the pilot's side of the center instrument panel is a row of three warning lights. The left one shows flashing red if the autopilot is disengaged by the interlock circuitry, indicating malfunction, or if the autopilot is turned off by means of the panel switch. Pressing the control wheel disengage buttons will turn the light off.

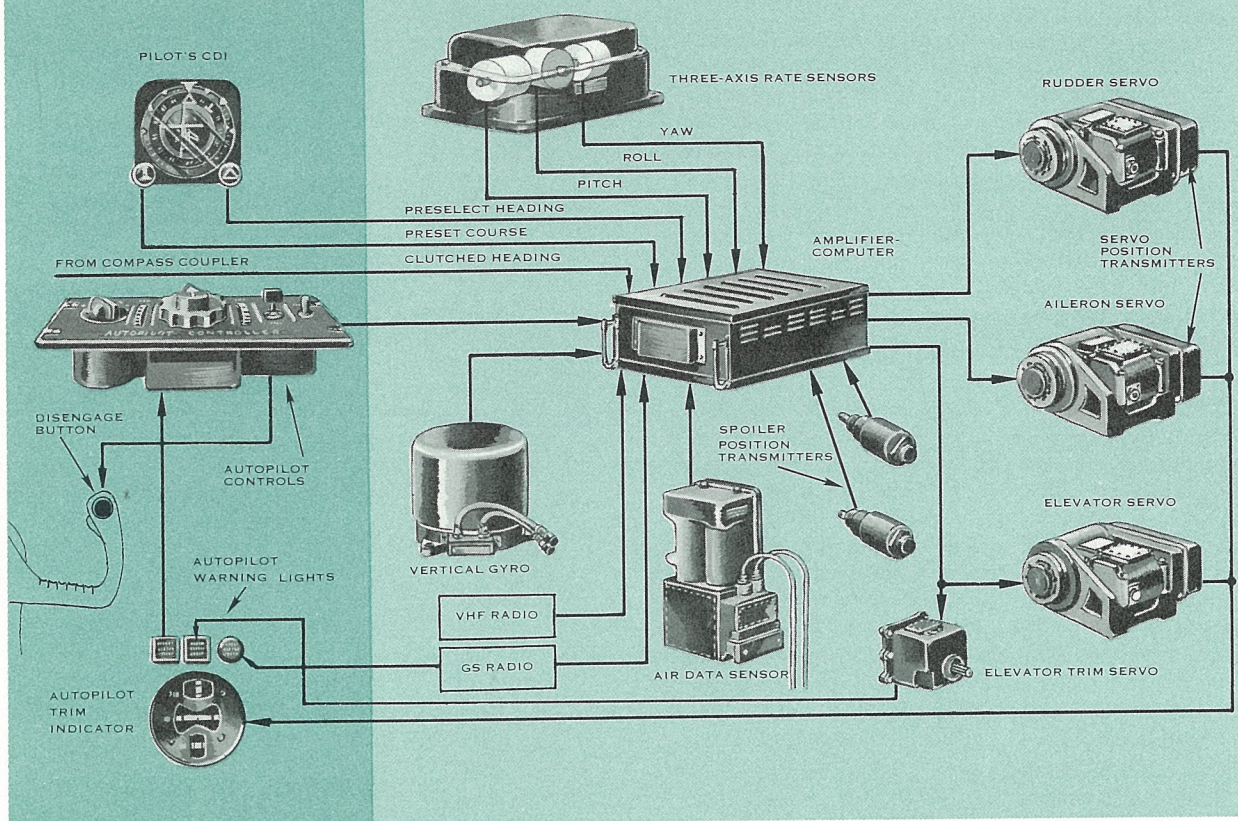
Illumination of the red center light indicates that pitch is out of trim. This light operates only in approach configuration — specifically, when the flaps are down. The right-hand GS ARMED blue light comes on when GS AUTO is selected, to indicate that the glide slope has not yet been intercepted; it extinguishes when the glide slope signal takes control of the autopilot.

The autopilot system provides for automatic pitch trim, but not for rudder or aileron trim. During auto-



Autopilot trim indicator shows servo trim load. Warning lights are AUTOPILOT OFF, PITCH TRIM OFF, or GLIDE SLOPE ARMED (for automatic intercept).

SCHEMATIC — AUTOPILOT SYSTEM



pilot operation, an out-of-trim condition will not be apparent in airplane attitude, since the autopilot servos will hold against the unbalanced pressures; some warning is therefore needed to show when control surfaces need trimming, so that sustained loading can be removed from the servos. Warning is provided by a three-axis trim indicator on the left side of the center panel. Out-of-trim is indicated by the movement of white bars in small windows in the instrument face; a sustained deflection of the vertical rudder bar to the right, for example, means that the rudder should be trimmed to turn the airplane right.

AUTOPILOT COMPONENTS

The basic sensors that govern autopilot operation have been mentioned. In brief summary, the components of the system are as follows:

The three gyro-actuated rate signal transmitters are mounted on a common base. The gimbal axes are oriented to each airplane axis; the rate signals are transmitted to an amplifier-computer unit by Autosyn synchros.

Static and dynamic air pressures are important factors in automatic flight control. Pitot and static pressures are conducted to the air data sensor, a high-precision instrument that supplies a signal propor-

tioned to indicated airspeed, and another proportional to altitude, to modify autopilot loop gains.

Rate gyro, compass, vertical gyro, radio, and surface follow-up signals are fed into the amplifier-computer; its output is to the servo motors that position the control surfaces. The computer unit is located in the electronics compartment and contains the electro-mechanical computers, limiters, relays, and transformers for autopilot control. The components are miniaturized plug-in card assemblies which can be quickly interchanged. Transistors, diodes, and magnetic amplifiers are used for amplification and phase discrimination.

Power is supplied through a power junction box. An adapter unit in the electronic rack contains potentiometer adjustments for adapting the autopilot to the particular flight characteristics of the airplane.

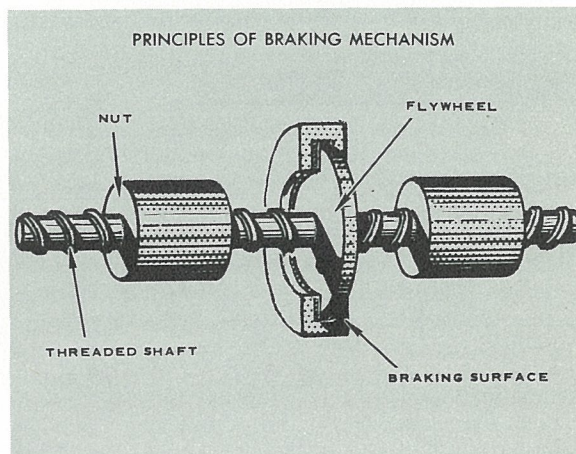
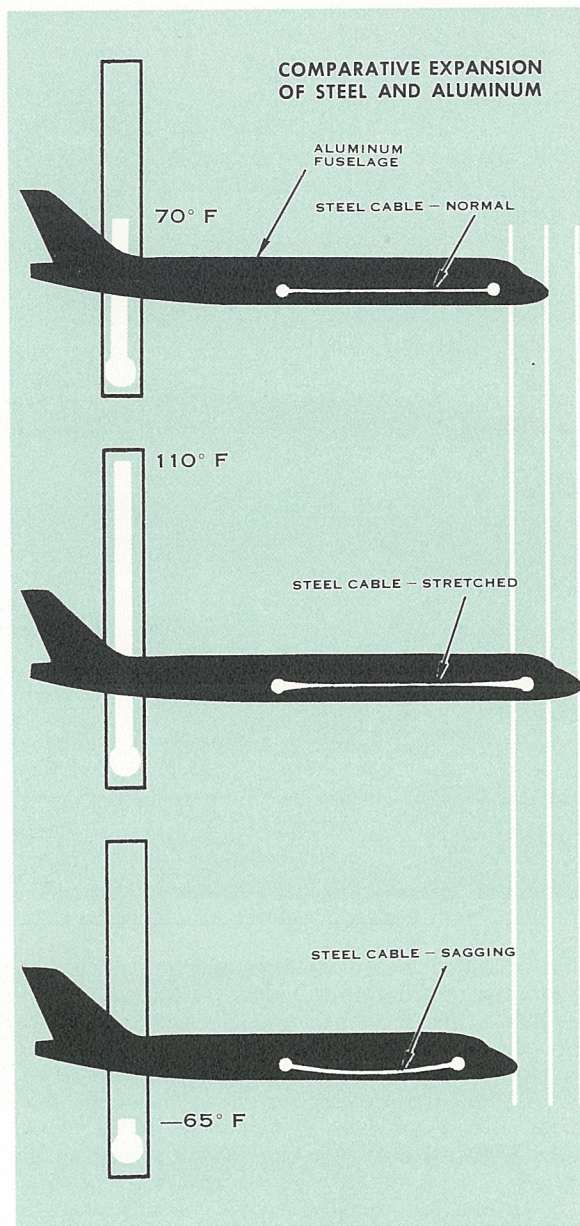
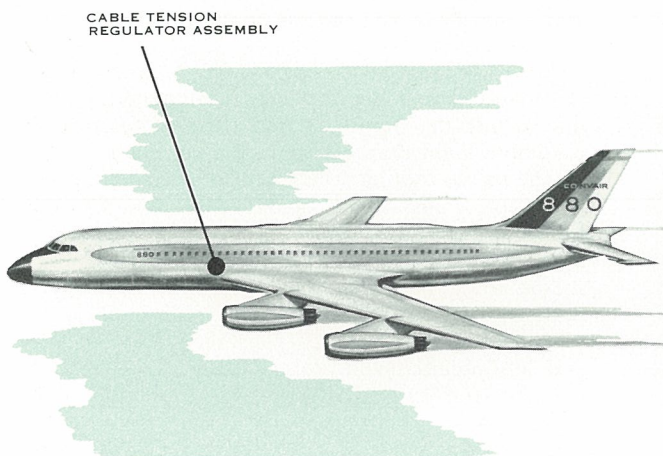
The servos that move the control surfaces are two-phase induction motors, operating the control cables through gear trains and magnetic clutches. Autosyn synchros on the output shafts transmit signals for follow-up; spoiler position is monitored by a special position transmitter. Rudder, elevator, and aileron servo motors have electrical resistance torque limiters, and a slip-clutch and torque limit disconnect. The elevator trim servo that operates the stabilizer has a slip-clutch and is electrically torque-limited to ensure safe operation.

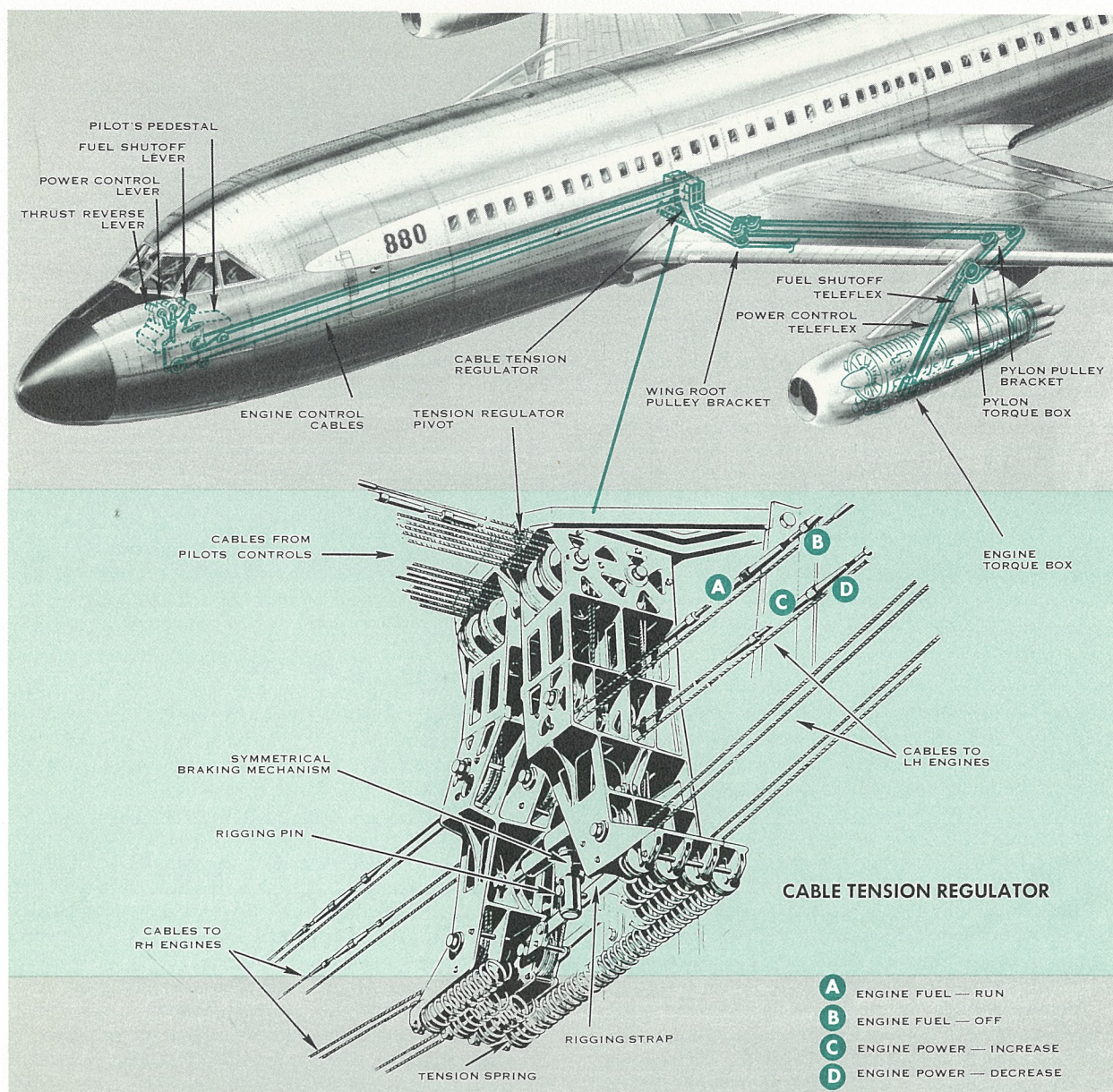
Convair 880/600 Cable Tension Regulator

In these days of high-altitude long-range flights, aircraft are being subjected to many conditions not normally experienced by their lower-flying, shorter-ranged counterparts. One of these jet-age conditions is the rapid and extreme temperature changes that take place on routine flights. Taking off under normal weather conditions, climbing to very cold altitudes in a matter of minutes, and later landing at perhaps a desert air terminal where the temperature is 110° F, causes quite a stir in the dissimilar metals incorporated in the design of a modern aircraft.

The difference in the coefficient of expansion between an aluminum airplane and its steel control cables would present a situation resulting in slack cables at cold temperatures and very taut cables at hot temperatures. As an example, at 160° F, an aircraft will expand .70 inch more than 100 feet of steel control cable, rigged for correct tension at 70° F. Uncorrected, this would put undue strain on the tightened system and, coupled with the added friction induced by pulleys and control mechanisms under strain, the controls would be difficult to operate. The opposite occurs when the temperature drops from 70° F to -65° F. The cable would then be slack because the airframe would be more than 1.00 inch shorter than the cable.

The engine fuel and power control cables, which extend through the unpressurized wing in proximity of hot compressor bleed air and de-icing ducts, pose problems associated with thermal variations and structural flexing. The solution to these problems took the form of a Convair-designed cable tension regulator that handles a total of 16 cables to all four engines. This compact single unit cable tension regulator is located at the center of the fuselage at the wing front spar. The engine fuel-power cable and pulley systems extend from associated quadrants below the cockpit floor at the pedestal, through the tension regulator, and out to the engine pylon torque boxes. From the





pylon torque boxes, the controls continue through teleflex cables to respective functions at each engine.

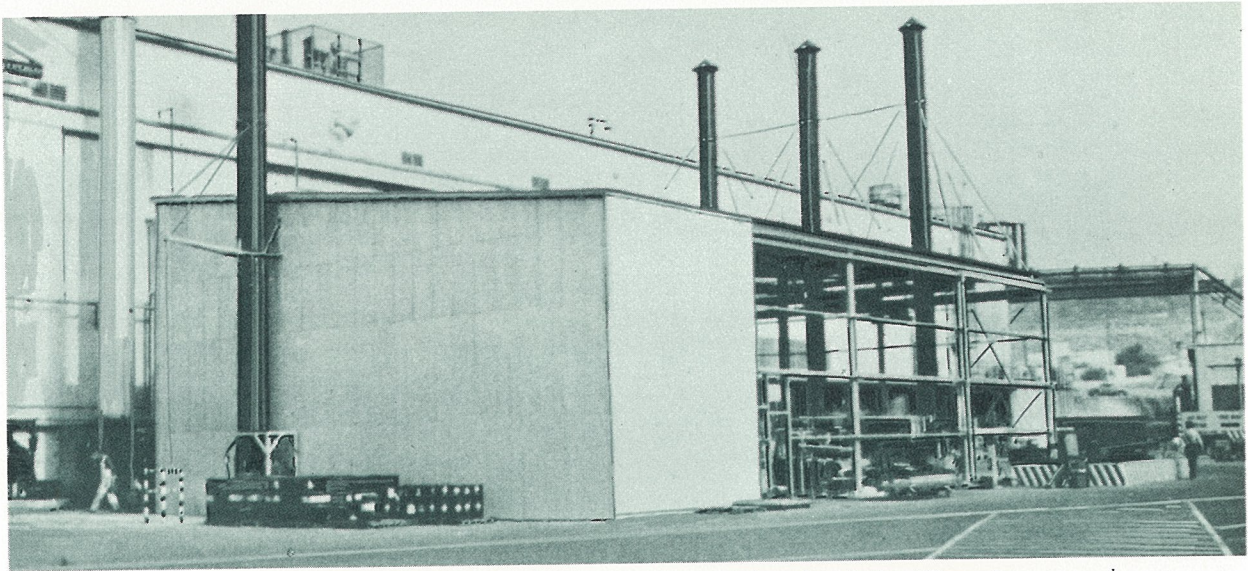
The heart of the 880/600 cable tension regulator is an ingenious mechanical device developed by the Pacific Scientific Company. Sometimes referred to as a braking mechanism, the unit consists of a shaft with opposing RH and LH high-lead threads and nuts on each end, with a captive flywheel in the center. The flywheel is between two braking surfaces and turns freely when centered. When an equal force is applied to both sides (as when the rig load changes), the nuts move, spinning the shaft and flywheel freely — as the thread pitches are added together. When the applied force is on one nut only (as when a control load is applied), the flywheel instantly comes in contact with a braking surface, freezing any motion of the

nuts. Regulator springs maintain an equal load on both sides of the system until a control load is applied.

The primary function of the tension regulator allows the pulley brackets to pivot symmetrically opposite at the centerline of the airplane to compensate for the change in lengths of the engine control cables in the wings. Without the regulator, the temperature changes between airframe and cables would result in cable tension loads of approximately 15 and 180 pounds at the two temperature extremes.

The braking mechanism of the regulator also allows all cable tension loads to increase or decrease slowly in the event of different temperatures in the wings. This condition would result if two engines on one wing were being run up simultaneously, or one wing was in the shade and the other wing was in the sun.

Chemical Milling



At Convair-San Diego, this building houses the facilities for chemical milling of parts made of steel, aluminum, magnesium, titanium, and many other alloys used in manufacturing.

The conservation of space and weight in Convair 880/600 jet airliners has led to extensive use of a relatively new milling process on structural material, called "chemical milling," or "dynamic etching." Because of the many complicated units and components installed aboard modern aircraft, space and weight are at a premium, and the consideration of these two factors is becoming increasingly important during aircraft design.

Chemical milling is just what the name implies — the removal of metal by controlled chemical reaction instead of by conventional machining processes where the metal is removed mechanically by lathes and mills.

Chemical milling reportedly had its beginning in the 15th Century, A.D., when European armorers etched crude decorative designs on their shields. The state of the art has remained fairly dormant over the years, with the operation being largely confined to small etching tasks. It was only when the aircraft industry began looking for a simpler and less expensive means of machining large and delicate parts and structures that the art showed a revival.

The need for an adequate fabrication process to handle the F-102A wing tip gave impetus to Convair's research and development work with chemical etching. By conventional methods of sheet metal construction, the F-102A wing tip required 56 detail parts. Chemical milling made it possible to build the wing tip three times as strong, four pounds lighter, twice the size, and with only 26 detail parts.

When the search began for an alternate method of constructing the wing tip, consideration was given to many processes. At that time, adhesive problems with honeycomb encouraged further search for a method that would result in material as light or lighter than

14 53
honeycomb and which would be feasible from a shop operation standpoint. When chemical milling appeared to be practical, it was decided to use a geodesic grid pattern for achieving lightness and strength. Time has proved the success of this approach.

Advantages of the chemical milling process are many. The process can be used readily after forming operations, whereas machining would be difficult, and, on some intricately shaped parts, almost impossible. Many portions of the aircraft skin and structure can be reduced in thickness to much closer tolerances than normal machining tolerances.

There are no limits with chemical milling in regard to shape of material. Complex shapes, broad or narrow cuts, and comparatively sharp corners may be handled in a single operation. Both sides of a sheet of metal may also be etched simultaneously, thus avoiding the warpage that results from removing the metal on each side individually.

The size of a piece of material that may be chemically milled depends solely upon the size of the processing facilities. The process can be applied to many types of metals — aluminum, magnesium, titanium, and various grades of stainless steel. Hardness of a material does not affect the removal rate in chemical milling, an important factor when engineers think in terms of alloy steel for aircraft design and construction. The deciding factor in this case is merely the type of solution, or "etchant," used.

The chemical milling process is also attractive from an economic standpoint, provided, of course, that a certain amount of ingenuity is used.

Precise control is required throughout the milling process and the element of time plays a major role, as can be seen in the following sequence of operations.

The part to be milled is cleaned with a diluted solvent, and then vapor-degreased with trichlorethylene, after which it is alkaline-cleaned for 15 minutes in an aviation cleaning solution. Then, the part is rinsed for five minutes in water at a temperature of 110° to 120° F. The part is deoxidized in a chromic deoxidant for 10 minutes and then rinsed in a cold tap water spray, as it is removed. The part is then dried in an oven or by infrared for 5 to 10 minutes at a temperature of 200° F maximum.

The maskant solution is prepared and the part coated by the most appropriate method. A solution such as neoprene with a resin base is normally used. There are four methods of masking — dipping, roller-coating, silk-screening, and spraying. Dipping with three or four coats is ordinarily the best method for deep etching. Spraying is also an effective method, but the extra equipment needed sometimes makes use of this method prohibitive. Roller-coating is used only for parts having large shallow contours, or that are too large for the dipping tanks.

All coats of maskant are normally applied the same day. After masking, the part is cured for one hour in an oven or by infrared at 210° F maximum temperature. The time of drying is increased proportionately for deeper cuts and thicker coatings. The areas from which metal is to be removed are outlined with the use of a template; then, the maskant is stripped from these areas.

Because the etchant removes metal at approximately an equal rate in all directions, the maskant must extend onto the etched area for a distance equal to the total depth of the etch. This area of metal removal is referred to as "eat back," and must be precisely computed.

After masking, the part is immersed in the etchant solution long enough to remove the amount of metal desired. If the part is to be tapered, it is lowered into the solution at a predetermined rate. Close control of the etching solution and process is required. As the part is removed from the solution, it is sprayed with cold water.

Etching a part to various depths is accomplished by unmasking the areas of deepest cut first and then progressively unmasking the remaining areas. This type of metal removal is called "step etching."

Position of the part in the etching solution is important. When the ionized elements in the etchant oxidize the metal and form a soluble salt, there is also a release of hydrogen gas. If this released gas is trapped on the surface of the metal being etched, the etching process slows down and may possibly stop. Thus, the area to be etched should be placed uppermost in the solution and, if the part is heavily contoured, it may be necessary to mask and etch various areas individually.

Etching is also affected by such variables as temperature, agitation, angle of immersion, and spacing of parts in the solution. The rate of etching depends directly upon such factors as direction of grain, alloy, previous heat treatment, and whether the material is clad or bare.

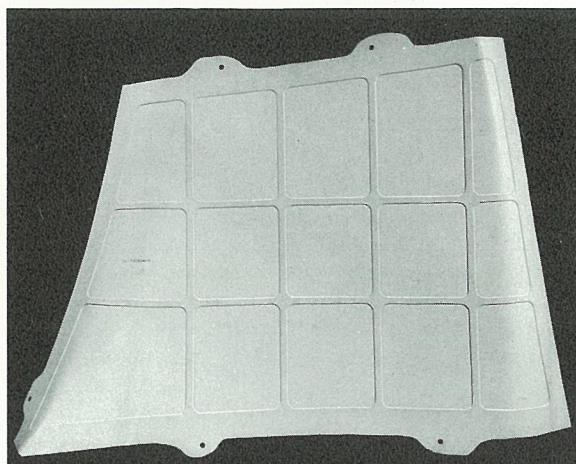
When variables are properly controlled, aluminum is removed at the rate of one mil (0.001 inch) per minute in all directions from the exposed or unmasked portion of the part. The following tolerances are considered realistic when etching aluminum:

DEPTH	* TOLERANCE
To 0.030 inch	±0.002 inch
0.031 to 0.060 inch	±0.0025 inch
0.061 to 0.090 inch	±0.003 inch
More than 0.090 inch	±0.004 inch

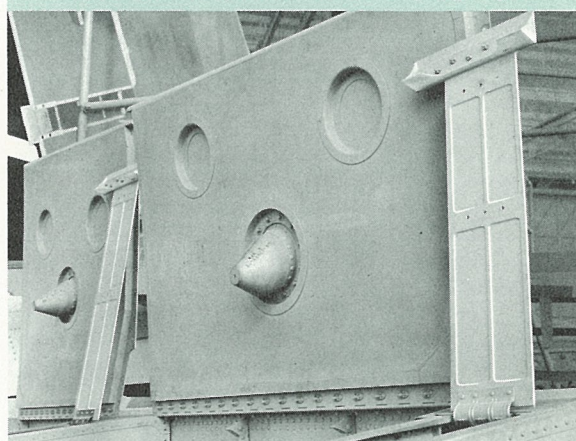
*Etching process tolerance only. Does not include sheet rolling tolerance.

After etching, metal is brightened for 3 to 5 minutes in chromic deoxidant after which it is rinsed again in a spray of cold water. The mask can be stripped off the metal, either by hand or mechanically, after soaking in hot water. The part should be allowed to dry for two minutes in an oven at 200° F maximum temperature.

By close control over a process long known but only recently exploited, Convair's interceptors and jet airliners are made lighter and stronger.



Convair 880 underwing fairing, milled in a pattern that preserves necessary rigidity.

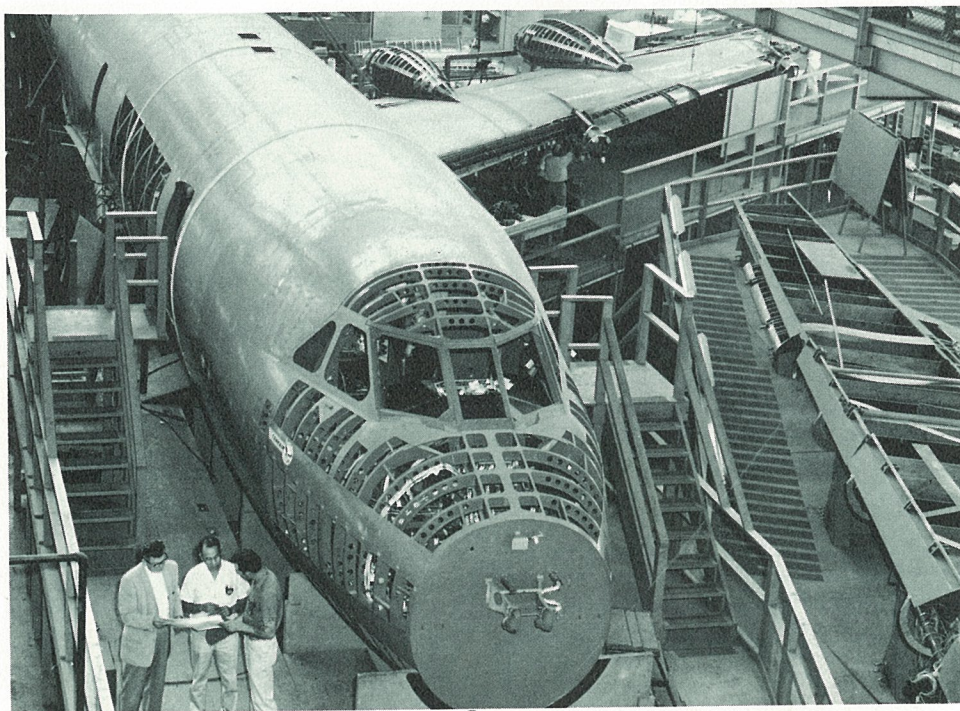


Etched balance board mechanism access doors are lighter without loss of strength, where needed.

An all-metal mockup of the Convair 600 jet airliner has been completed at Convair (San Diego) Division of General Dynamics Corporation.

The metal structure, built in production fixtures, is only partially covered with aluminum alloy metal skins and exposes such structural assemblies as belt-frames, bulkheads, floor beams, spars, and stringers.

The wing of the mockup, as shown in the photo, provides a relative view of the leading edge slat mechanism which will be used to achieve shorter landing and take-off distances, and of the speed capsules, or aerodynamic anti-shock bodies, which will enable the Convair 600 to fly at 635 miles-per-hour as the world's fastest airliner.



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Convair was the first in the industry to utilize the metal mockup concept — a three-dimensional “proving ground” for engineering designs and for exact placement of electrical harnesses, tubing, hydraulic lines, cables, and associated systems and controls.

Airlines purchasing Convair 600's are Swissair-Scandinavian Airlines System, Real Aerovias of Brazil, and Civil Air Transport, airline of the Republic of China. The first Convair 600 is scheduled for factory completion in July and its first flight is anticipated in September.

CONVAIR SAN DIEGO

CONVAIR DIVISION

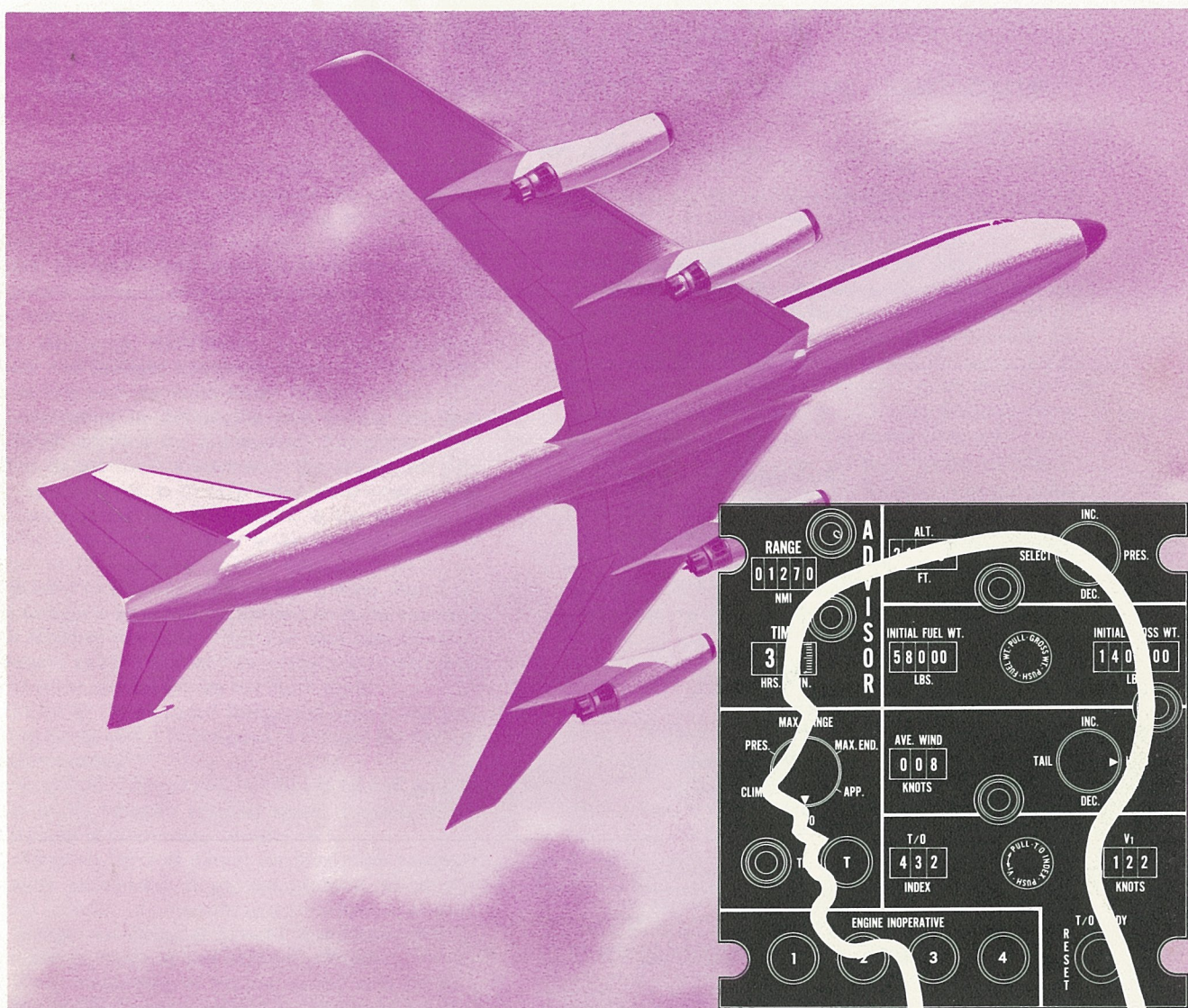
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VOLUME XI

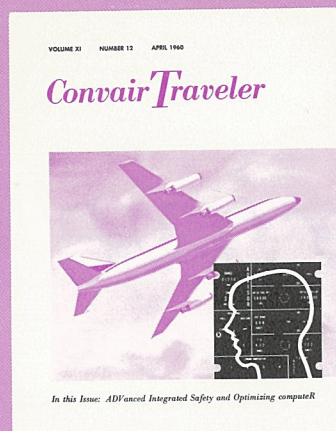
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Convair *Traveler*



In this Issue: ADVanced Integrated Safety and Optimizing computeR



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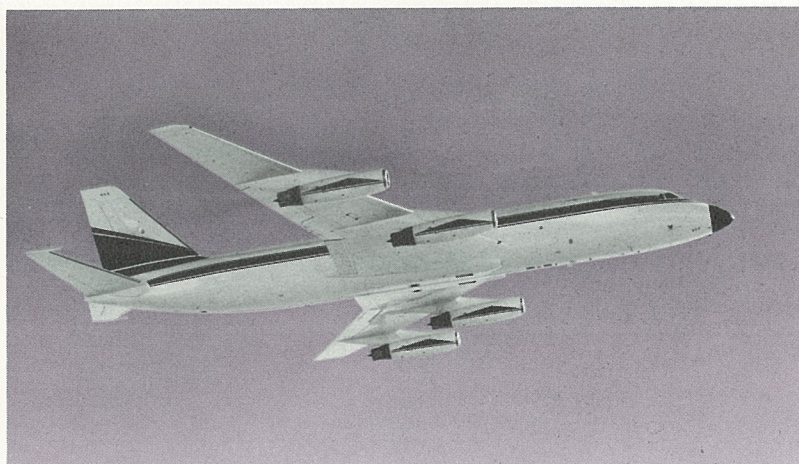
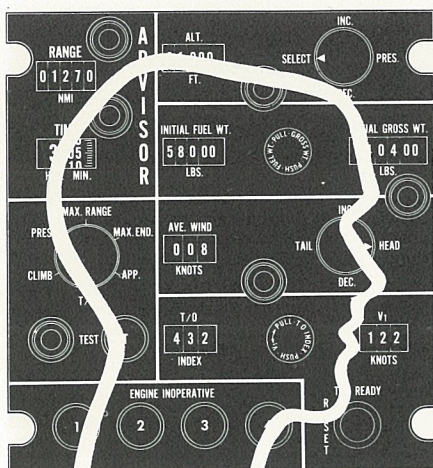
PLASTICS IN THE
 CONVAIR 880/600
Sam Urshan

A digest of operation and service published monthly by the Service Publications Sections of Convair Customer Service Department in the interest of Convair operators. Communications should be addressed to the Manager of Customer Service Department, Convair, San Diego 12, California. Information is to be considered accurate and authoritative as far as Convair approval is concerned. FAA approval is not to be implied unless specifically noted. Recipients of this information are cautioned not to use it for incorporation on aircraft without specific approval of their cognizant organization.

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OUR COVER

ADVISOR is an analog computer. The implied analogy is evident to Artist Norm Rutherford: ADVISOR, constantly monitoring the flight over the pilots' shoulders, proffers expert advice, based on thorough briefing and comprehension of the situation.



ADVISOR

ADVanced Integrated Safety and Optimizing computer

In the flight compartments of each of two Convair 880 test aircraft, on the console to the right of the copilot, is a small panel containing several digital counters and adjustment knobs. Unobtrusive as it appears, this panel may make more difference in the navigator's chore in commercial transports than any other one of the manifold aids to navigation.

The device is ADVISOR, a combined takeoff monitor and in-flight computer. Convair Flight Test Engineering and the John Oster Manufacturing Co. are cooperating in developing and testing the first ADVISOR adapted for commercial transports. Convair has no proprietary interest in the device; the primary consideration is to help solve some operational problems that are becoming acute in the jet age.

Flying a mile every six or seven seconds, burning a barrel of JP-4 every couple of minutes, a jet transport is hard to keep up with, in more ways than one. "Stop to light a cigarette," a harried jet flight engineer told a reporter last year, "and you may lose track of a thousand gallons of fuel." Planning and re-planning a flight is the busiest job on the flight deck.

ADVISOR (ADVanced Integrated Safety and Optimizing Computer) is designed to present the following information:

1. Required airspeed buildup during takeoff ground run-up to V_1 velocity (refusal speed, beyond which the airplane is committed to take off).
2. Airspeed for best climb; for maximum range or maximum endurance at present altitude, or at any selected altitude; or optimum speed for final approach.
3. Range remaining at present speed and altitude, or maximum range at any selected altitude.
4. Time remaining at present speed and altitude, or with maximum range setting at other selected altitudes; or maximum endurance time at any selected altitude.

5. Range and time figures in engine-out operation.

Already proved in a jet bomber flight test program, ADVISOR is being installed in a class of military turboprop transports. With Convair's aid, it is being adapted for "880" and "600" jet airliners.

Convair pilots and engineers believe that the development of such a computer is inevitable. Flight planners and navigators have better instruments and more facilities available every day; but, the plain fact is that, while navigation is far more exact than during World War II, for example, it is also more exacting; the time required for the job hasn't lessened.

The B-25 "bombigator," without having to "fiddle" with LORAN squiggles or VORTAC radio and radar beams, was still never bored on long missions. He was too busy plotting wind vectors, thumbing through his files of charts and nomographs, and "working cruise control"—running endless problems of how far and how high he could travel on how much fuel. His tools were his flight handbook, Weems plotter, and E-6B circular slide rule.

That part of the job hasn't changed. At this minute, there are pilots and navigators all over the world leafing through their papers for the proper fuel consumption graph and twirling their card computers to estimate fuel weight on arrival and possible alternate flight plans. If the airplane involved is a jet transport, there isn't much time, and the navigator's answer had better be correct; by the time he rechecks, he's somewhere else.

ADVISOR, in addition to aiding the pilot during takeoff and landing, is designed to take over this in-flight chore. Plotter and slide rule will still be at hand for preflight planning and map work; but after takeoff, ADVISOR proposes to retire the E-6B to standby status, where it should be in a jet age. ADVISOR will actually save the crew some time.

Convair's involvement in ADVISOR tests originally grew out of interest of flight test men, headed by Don Germeraad, chief test pilot, in a takeoff monitor—a device that would warn a pilot when his runway acceleration is less than it should be. Several designs have been suggested and tried out by various manufacturers. In discussions between Convair and Oster engineers, it was brought out that the potentialities exist for a much more sophisticated computer.

Consider what a takeoff monitor must do: First, it must absorb information about airplane gross weight and the runway—altitude, temperature, etc. Then, it must supply information about the airplane characteristics—relative effects of the variables on acceleration at takeoff thrust, and the airplane's standard runway requirements. The monitor mechanism, in other words, must be tailored to reflect the applicable graphs in the flight handbook. Finally, the mechanism must integrate takeoff and runway variables with the aircraft characteristics and make the results of this computation available to the crew, by indicator, warning horn, or some other such means.

Such a takeoff monitor is possible, it is generally agreed. That being so, the reasoning was, why not go farther and build into the computer more of the airplane operating characteristics—mechanize more of the flight handbook? If the proper settings for flight characteristics at various speeds and altitudes are designed into the computer, all the data are at hand to solve standard cruise control problems. Parameters for fuel quantity, rate of fuel flow, outside air temperature, and airspeed are already available in instrument systems. As has been pointed out in recent Traveler articles on instrumentation, this information is available in the form of electrical signals, which

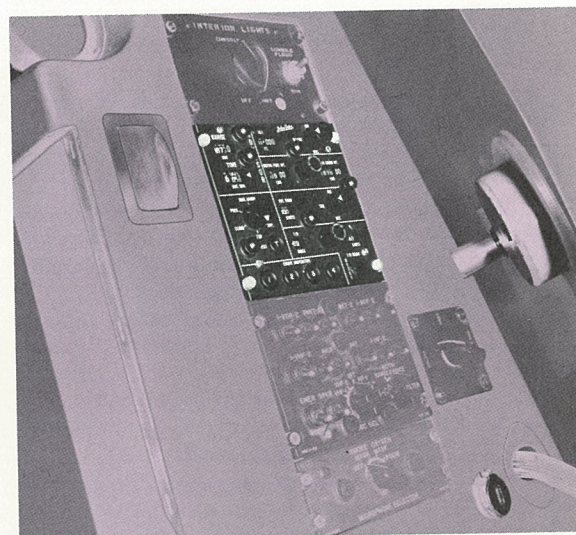
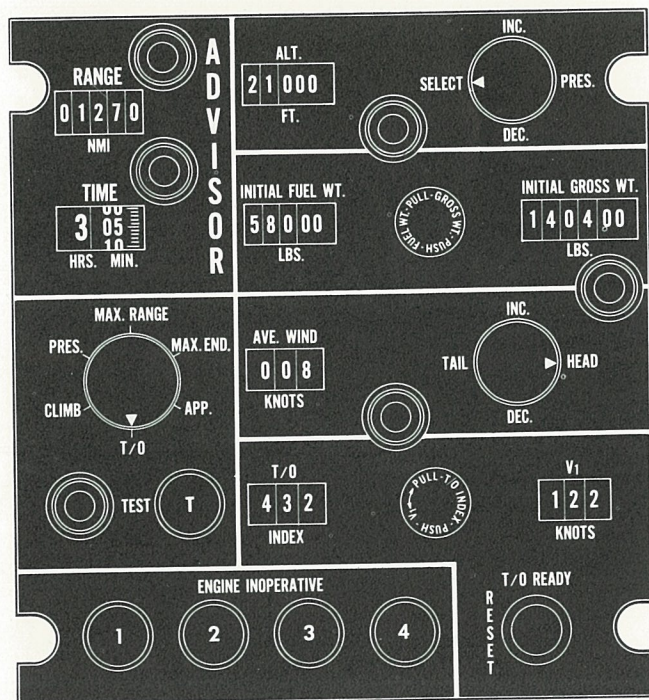
can be fed into an electro-mechanical computer.

Outcome of consultations between Oster and Convair engineers was an arrangement whereby the Oster company, with long experience in manufacturing precision synchros and servo components, would make up the test units, and Convair in its flight test program would try them out. ADVISOR units were made up and installed in the first two "880" flight test aircraft. Each consists of a flight compartment control box and panel (pictured herein); a computer unit, acceleration switch, and altitude transducer (the only sensing unit in the ADVISOR system) in the electronics compartment; and a modification to the Kollsman indicated airspeed instrument to add a pair of triangular markers on the periphery of the dial.

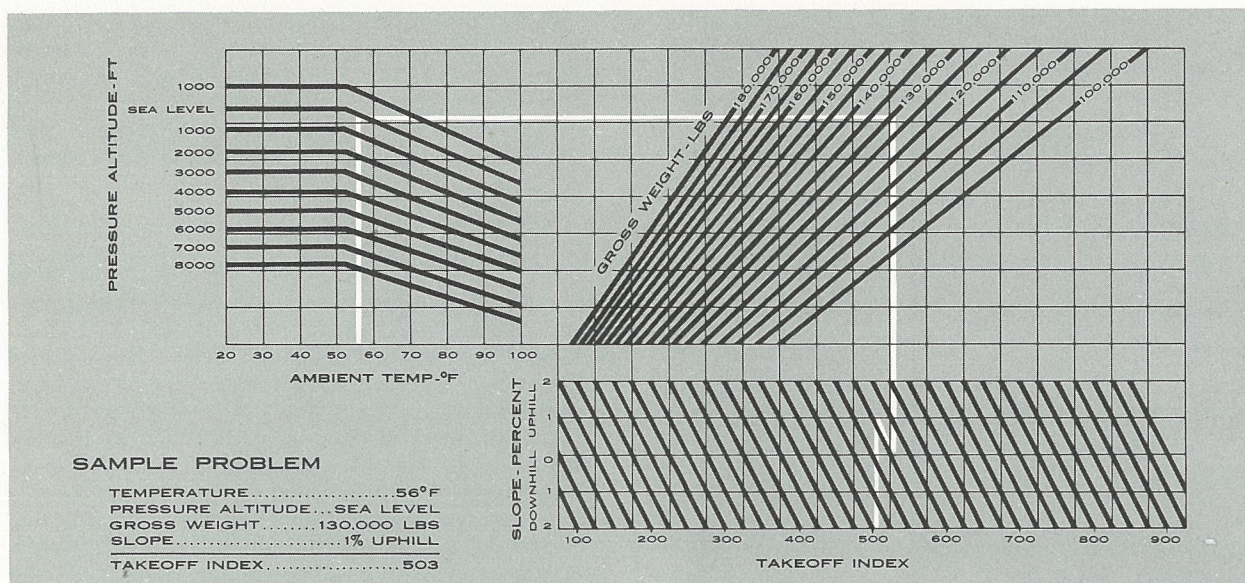
The indications are read on the IAS indicator and on a pair of digital counters at upper left on the ADVISOR panel. One of the markers on the IAS dial is for V_1 speed; the other, commonly termed the "bug," is an acceleration marker on takeoff, and a speed command marker in flight. Range and time remaining appear in the panel counters. A switch on the panel selects the mode in which the computer operates.

Following is the procedure for using ADVISOR in a typical flight, with a more detailed description of the indications given and the factors taken into account by the computer in each mode.

As part of preflight preparation, airplane gross weight and fuel weight are set into the control panel by use of a two-position knob (PUSH FUEL WT/PULL GROSS WT) on the panel. V_1 speed is determined from charts and set by the PULL position of another knob; also, the marker on the IAS indicator is manually moved to this V_1 speed, by rotating the dial cover glass.



"880" test ADVISOR panel is on copilot's RH console. Settings are typical for light-load takeoff. RANGE and TIME counters are normally masked during takeoff mode operation.

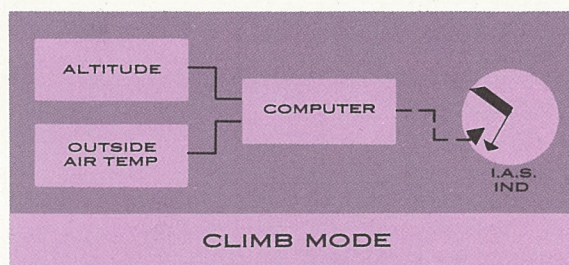
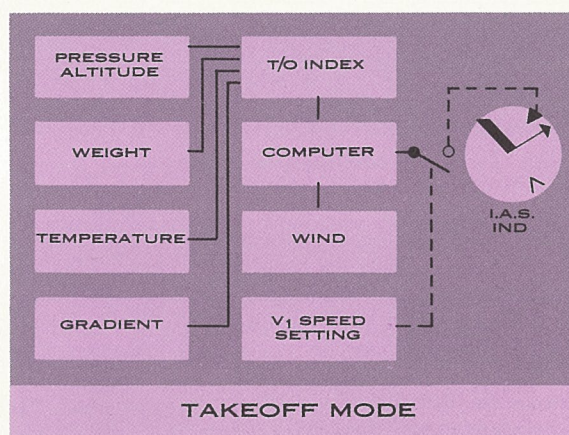


The PUSH position of the latter knob is labelled T/O INDEX, and a counter appears beside it. The takeoff index is an arbitrary figure. The pilot enters a chart with ambient temperature, pressure altitude, airplane gross weight, and runway gradient, and arrives at an index number representing a combined function for these variables. By means of the T/O INDEX knob, he sets this number on the adjacent counter.

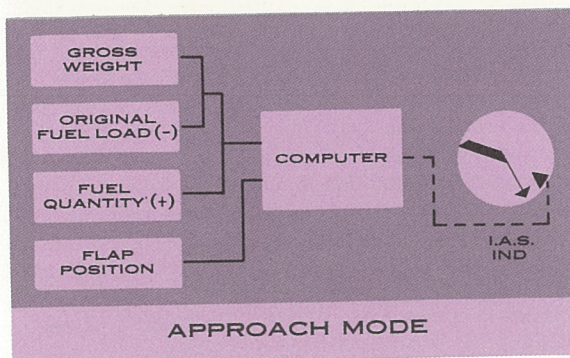
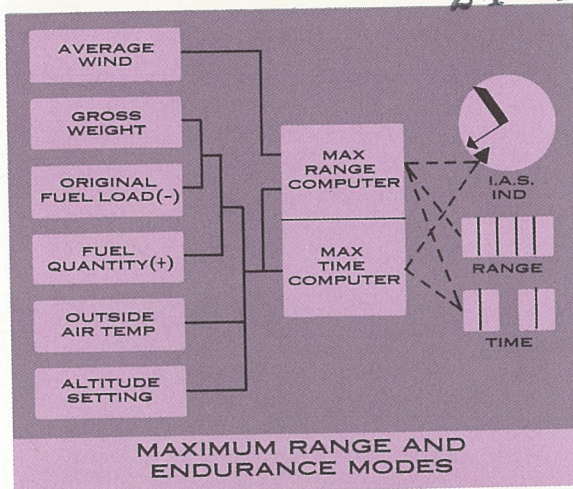
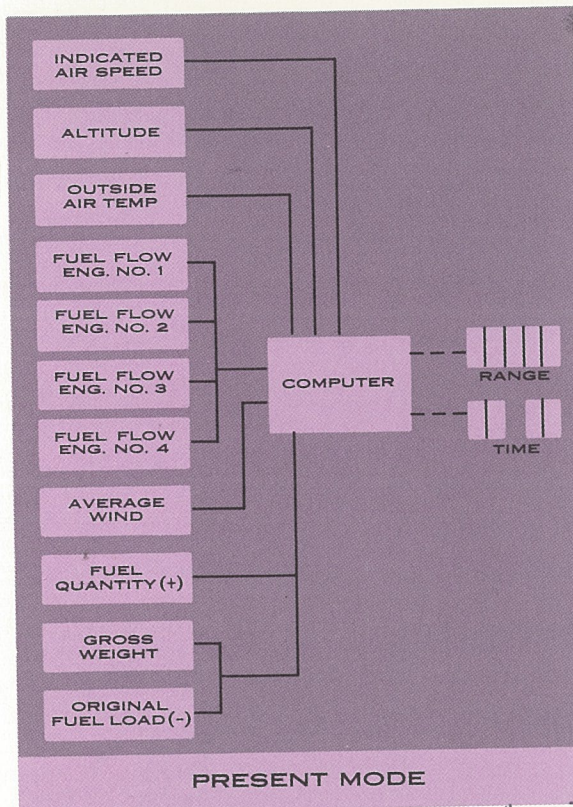
Runway head or tail wind component is set into the average wind (AVE WIND) counter. The knob for this setting is turned left for tail wind, right for head wind. Finally, the mode selector is turned to T/O position, and a RESET button pushed. A green T/O READY light in the button illuminates if the system is armed.

When brakes are released and the airplane begins its takeoff run, an acceleration switch closes, the green light extinguishes, and a timer begins feeding a signal into the computing mechanism. The timer signal represents a function of the acceleration at takeoff thrust necessary to meet the FAA-prescribed takeoff distance requirements; this signal is summed with the takeoff index and wind functions, to drive the bug on the IAS indicator.

The bug moves around the airspeed dial at a steady rate, representing a safe minimum acceleration schedule, which will be somewhat less than normal takeoff acceleration. As airspeed builds up, the airspeed needle should quickly pass the bug and stay ahead of it up to V_1 speed. If the bug at any point in the run begins to creep up on the needle, acceleration is not normal. This may represent merely a puddle on the runway; however, it may mean reduced thrust, dragging brakes, or some other malfunction. In any case, if the bug overtakes the needle near V_1 speed, the takeoff should be aborted. At V_1 speed, since the airplane is committed, a switch cuts off the signal and the bug remains at V_1 .



When the airplane is airborne, cleaned up, and throttled back to climb power setting, the mode selector switch is turned to CLIMB. Then the same bug moves around the IAS dial to mark the speed for optimum (maximum fuel economy) climb. The climb profile maintains a constant equivalent airspeed up to a certain true airspeed, and maintains the true airspeed for the rest of the climb. Optimum speed is computed from the altitude transducer and the outside air temperature signal supplied by the Kollsman Integrated Flight Instrument System (KIFIS).



For cruise control, there are three settings of the mode switch. To compute time and range remaining at present altitude and airspeed, average wind for the course is set into the AVE WIND counter, and the mode switch is turned to PRES. Range and time remaining appear on the ADVISOR panel digital counters.

This computation is perhaps the most complex of the various modes. Current fuel quantity is obtained from the Simmonds fuel gaging system; altitude from the altitude transducer; and outside air temperature and indicated airspeed from the KIFIS system. Gross weight setting on the panel counter is diminished by the amount of original fuel load, and present fuel load (from the fuel gaging signal) added back on, to yield a function for present weight. The fuel quantity signal is also fed directly to the computer. Rate of fuel consumption is obtained by summing the signals from the four General Electric engine fuel flow transducers. All these signals are combined with the built-in functions for aircraft performance, to drive the range and time counters.

When maximum range available at any specific altitude is required, the pilot uses the altitude selection knob, at the top of the panel shown. He sets in average wind as in PRES mode, and turns the mode switch to MAX RANGE. RANGE and TIME counters will turn to the proper figures, and the IAS bug will move to the required speed for obtaining maximum performance. If the airplane must climb to the selected altitude, the computer takes into account added fuel consumption during climb.

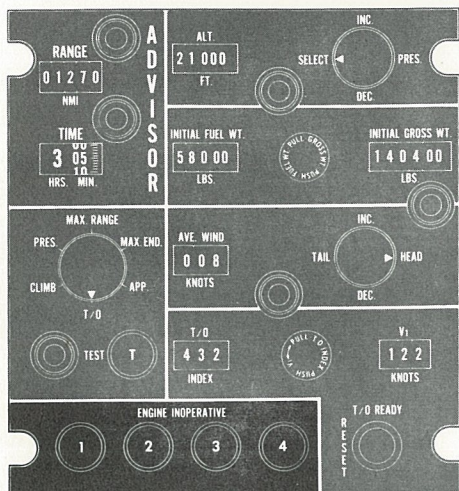
Finding the absolute maximum distance the airplane can fly entails finding the maximum of the maximum ranges at other altitudes. This can be quickly done by turning the ALT counter slowly up or down, until it is apparent that a peak reading has been reached on the RANGE counter. The ALT counter will then show optimum altitude for maximum range.

For maximum endurance at present altitude, or at any selected altitude, the same procedure is followed, with the mode switch at MAX END. The bug will show IAS for minimum fuel consumption, and maximum endurance time will appear on the TIME counter. Since range is usually not of primary importance in such a situation, the range counter will be masked off. Optimum altitude can be determined as in the range mode computation.

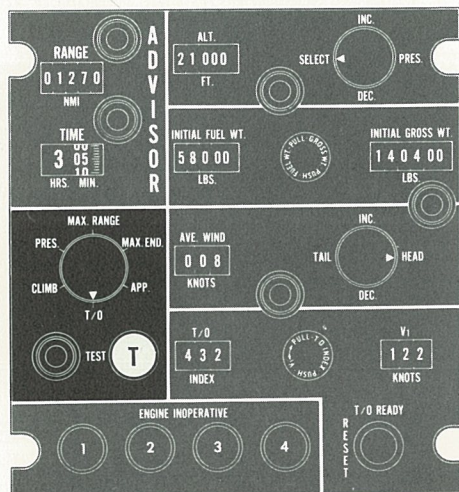
Computer inputs for maximum range and endurance modes are almost identical; the computer's parameters for performance are what change. Fuel aboard, and outside air temperature, are obtained from instrumentation. Gross weight is corrected by the fuel-aboard signal, and average wind is set in manually (for use in range computing only). In place of the signal for actual altitude, a signal representing the selected altitude is fed in via a potentiometer, controlled by the altitude selection mechanism.

Approach mode is one that interests some operators as much as takeoff mode. The mode switch is

turned to APP. The signal that drives the bug represents a margin over stall speed, which is a function of airplane maximum lift/drag ratio. Gross weight and flap setting are the variables. Flap setting is obtained from the flap position transmitter. The bug on the IAS will mark a minimum safe speed during approach, right on down to the over-the-fence phase of the landing.



Four buttons in the ENGINE INOPERATIVE section of the panel are for use in cruise computing modes. If No. 1 engine power is lost, or if the pilot merely considers shutting it down, pushing the No. 1 button will cause the computer to re-figure range and time, making allowance for loss of power and the aerodynamic effects of three-engine operation. The computer distinguishes between inboard and outboard engine-out drag and asymmetric trim. For two engines out, the signals are so summed as to provide proper readings for any combination of inboard and outboard engines, including two out on one side.



The TEST button beside the mode switch provides a means for a quick check of computer operation, either on the ground or in flight. Similar to the KIFIS test switch, it feeds in signals that represent certain

settings of the range, time and wind counters and of the bug on the IAS dial.

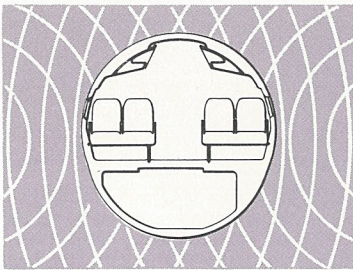
Accuracy of ADVISOR was checked at better than 99% in the military bomber version. This does not mean, of course, that an airplane would run out of fuel on the exact mile that appears in the range counter; ADVISOR can be only as accurate as the information fed in, and neither fuel gaging systems nor performance charts are that precise. What the accuracy figure does mean is that a pilot has at his fingertips a mechanized handbook combined with calculator, which will give him, rapidly and automatically, an answer better than 99% of what he would get by the most meticulous calculation from his charts and instrument readings—and give him more answers in half a minute than he could work out in half an hour.

This immediate access to optimizing calculation is of primary importance in flying economy. In a survey of operations of one type of jet bomber over a year's time, it was found that fuel consumption degradation ran 5% to 8% from optimal; that is, the bombers used that much more fuel than they needed to, had the flights been planned with closer adherence to performance charts. With fuel loads at 50,000 to 100,000 pounds and more, percentages like that become important to commercial operators.

Other parameters—engine pressure ratio, total thrust, Mach number, or true airspeed, for example—can be used in such a computer, and other optima obtained. The ADVISOR configuration now being perfected in "880" test flights is adapted for the Convair jet airliners, to yield the information commercial operators need. It reflects the wide flying experience of Convair pilots in many types of aircraft. They turned thumbs down, for example, on a takeoff warning light or horn; during ground run, they had rather keep fire-alarm-size warnings for major emergencies. They did not care for an extra bank of engine thrust indicators, since pressure ratio and tailpipe temperature are fair measures of engine efficiency. They did request the takeoff warning on the IAS indicator, plainly visible to the pilot during the quick glance he can spare during takeoff roll.

As any electrical engineer well knows, it is always quite a way from an admittedly workable idea to reliable hardware. Since mid-1959, when the first ADVISOR began operating on "880" No. 1 test airplane, many components have been modified. "Shaped pots" have been reshaped, inputs have been juggled experimentally to yield varying types of readings. Flaws have been painstakingly weeded out and, so far as the "880" is concerned, finalized design is in sight.

When that time comes, John Oster Manufacturing Co. will have an ADVISOR ready for the production hardware stage; Convair will have made a necessary major contribution in a highly important field of development; and "880" and "600" operators will have available a device of great potential value with respect to flight safety and operating economy.



Fuselage Sound Attenuation

CONVAIR 880/600

Hushing the luxurious interior of the Convair 880/600 jet airliner to a sound level that will allow comfortable conversation between passengers has been achieved.

As the swift jet airliner speeds through the upper atmosphere at near sonic velocities, the sound of the air rushing over the skin tries to enter the fuselage shell. This aerodynamic sound, coupled with the noise created by the jet engine blast striking the aft portion of the fuselage, would become loud and annoying if left unabated. Inside the cabin there are additional sources of noise created by the ventilation system and the operation of auxiliary equipment. These, too, had to be subdued to attain a hushed cabin interior.

Convair acoustical engineers set about to achieve their goal of the quietest jet airliner in a manner that "left no stone unturned." Their greatest concern was in two types of sound: noise caused by the jet engine exhaust, and noise generated during flight by the friction of the air passing over the fuselage skin.

The decision to accept the design concept of a double wall construction for the passenger cabin to counteract aerodynamic noise was made early in the design stage of the Convair 880. This led to the adoption of a relatively heavy outer skin and inner trim panels of special sandwich construction with glass fiber blankets between the walls. The heavier outer skin not only resulted in improved low frequency sound attenuation, but also saved stringer weight by reducing the number of stringers required.

The fiber glass blankets between the thick skin and the interior trim panels proved effective against the high frequency sounds.

It was also determined that the fiber glass blankets were more than adequate for thermal insulation and for the prevention of moisture condensation in the fuselage structure during rapid changes in temperature.

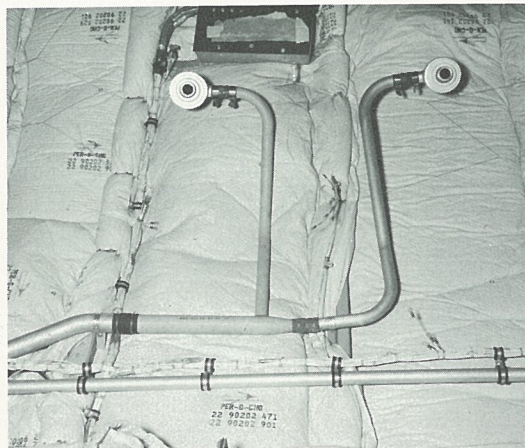
To further develop and refine the "880" sound attenuation program, Convair built a special acoustics laboratory facility. This laboratory consists of two buildings: the basic laboratory, and a fuselage section building. The basic laboratory has adjoining test rooms which represent the opposite in acoustic environments—an anechoic (echo-free) wedge-lined room, and a reverberation room with smooth hard walls to reflect back sound. Various cabin wall panels were placed between the two rooms, and tested for their noise barrier effectiveness.

A 19-foot section of the Convair 880 fuselage was placed inside the fuselage section building with the ends of the section carefully sealed to allow noise to enter only through the sides. Loudspeakers placed in the corners of the room were used to produce uniform sound fields over the entire outside of the section. Thus, any number of sound conditions could be simulated and tested inside the fuselage section.

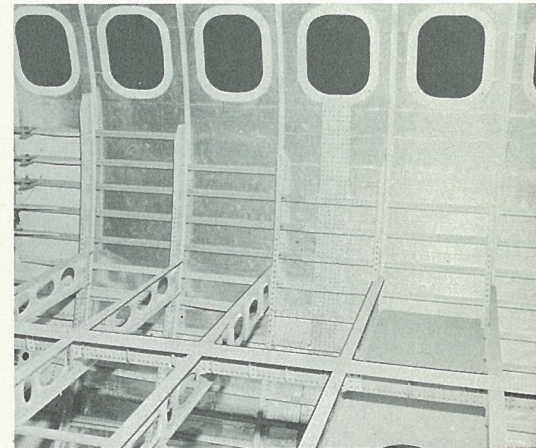
By fully utilizing results from this development program, Convair was able to gain accurate knowl-



Thermal and acoustical insulation blankets are tailored to fit snugly around all windows and doors.



To facilitate inspection and maintenance, the blankets are installed outboard of wiring and plumbing.



Damping tape of aluminum foil is applied to the inside of the skin panels in the engine exhaust areas.

edge of material and component performance, and to develop new materials and installation methods. In carrying out a balanced design concept and reducing weight by refinement of design, Convair engineers pared off almost 25 percent of the weight from the original acoustical treatment allocation.

The thermal and acoustical insulation blankets, used to line the interior of the "880/600," are made from low density fiber glass matting. Composed of 0.00004 inch diameter glass fibers, these mats form, in most cases, four-inch-thick blankets. To safeguard against moisture, the blankets are encased in lightweight waterproof nylon fabric which is also Skydrol- and fire-resistant. Occasional small diameter breather holes are provided in the covering to assure even pressure throughout the blanket.

The double wall construction of the Convair 880/600, using interior trim panels in conjunction with outer skin, eliminated the need for internal septums within the insulating blankets. This resulted in blanket weight reductions up to 30 percent without lowering blanket insulating effectiveness.

The blankets are tailored to fit snugly between the fuselage beltframes and around windows and openings. Attached to one edge of each blanket section is a flexible flange which is wrapped around the belt-frame and held in place by metal clips. This flange, in turn, holds the adjoining blanket edge in place while the opposite flange wraps around the following belt-frame, and so on.

The blankets are installed outboard of all tubing, wiring, and ducting, thereby practically eliminating the need for disturbing the blanket placement during normal inspection and repair operations. Slitting or piercing the blankets is held to an absolute minimum to prevent sound leaks.

Nylon cords, criss-crossed against the insulating blankets, hold them firmly against the fuselage skin and prevent them from sagging. The blankets are attached to the airframe in this manner so that they can

be easily removed to facilitate repair or maintenance of the fuselage structure.

In the aft portion of the fuselage, from the proximity of the wing trailing edge to the empennage, measures were taken to attenuate the noise of the jet engine blast. Successful results were obtained by applying a damping tape consisting of pure aluminum foil with a special adhesive to the inside of the skin panels between the beltframes before the installation of the fiber glass blankets.

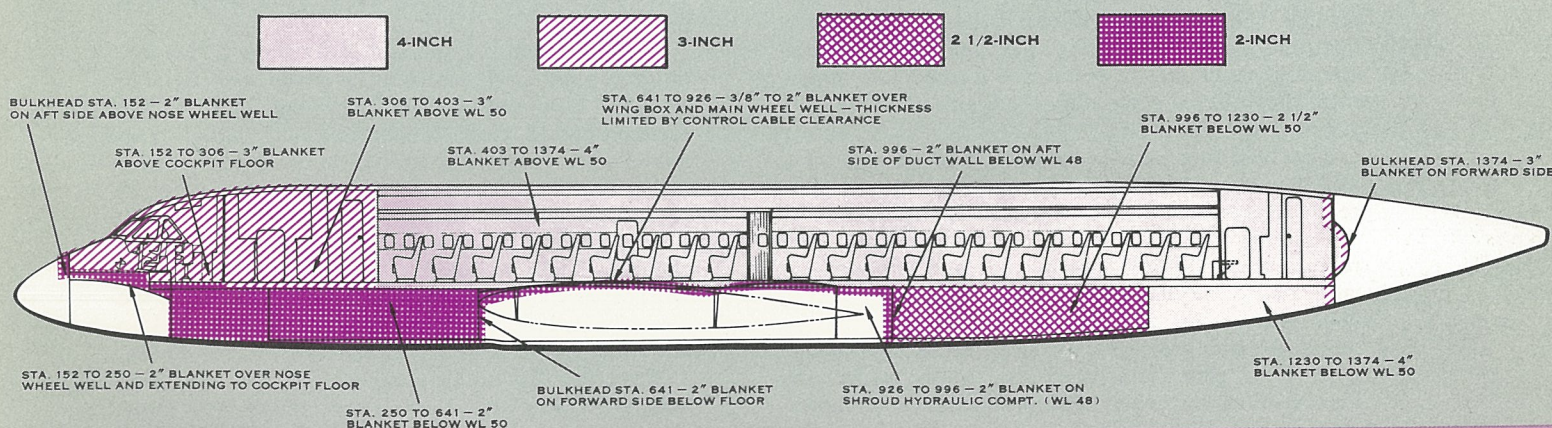
Varying in foil thickness from 0.008 to 0.012 inch, the damping tape is built up in different layers and schedules, depending on the location of the panel and the extent of damping required.

The passenger windows on the Convair 880/600 complement the insulating blankets and damping tape in the control of heat and sound. Each consisting of three panels separated by air spaces, the windows act as a very efficient thermal and sound barrier. To insure adequate quieting of jet exhaust noise, the windows in the aft section of the fuselage have thicker inner panels. As a further step in arresting sound, all inner window panes are mounted in soft rubber retainers.

The engine sound suppressors, although designed for external sound control, proved just as effective in reducing low frequency noise inside the aft portion of the cabin.

Fiber glass reinforced plastic is used extensively throughout the airplane as a thermal insulating medium between the primary airframe structure and interior installations. Rubber grommets are used between basic structure and interior trim to isolate vibration and to aid in overall sound attenuation. Interior trim brackets, and many other plastic fittings add to the cumulative result of an insulated interior.

Upholstery, carpets, drapes, and even the passengers themselves contribute to the final hushed environment of the passenger compartment on the Convair 880/600—the quietest jet airliner.



BLANKET THICKNESS DIAGRAM

Plastics in the Convair 880/600



Plastic aircraft components, ranging from fiber glass reinforced structural parts to decorative interior trim, are being used more and more in modern aircraft. Applications of plastic in aircraft construction have proved to be sound, and new uses are constantly being incorporated into advanced designs. This versatile material is being used extensively throughout the Convair 880/600 jet airliners.

Some of the advantages of plastic are its ease of fabrication, its dielectric qualities, weather and abrasion resistance, low specific gravity, and desirable thermal characteristics.

Reinforced with fiber glass, plastics become even more versatile. The tensile strength of a fiber glass laminate may be as high as 100,000 psi, depending on the resin and glass reinforcement used. Many reinforced plastics have useful temperature ranges up to and above 500°F and, under extreme cold conditions, these plastics tend to grow stronger, but more brittle.

Plastics fall into two basic classifications: thermoplastic and thermosetting. Thermoplastics soften when heated, and harden when cooled; they can be reshaped again and again by alternate heating and cooling. Thermosetting plastics harden (cure) under heat into a permanent shape. Through an irreversible chemical reaction, the resins are formed into single three-dimensional molecules. Additional heating will not fuse the materials.

Thermosetting plastics include polyesters, epoxies, and phenolics; in this family are found most of the reinforced plastics used in aircraft applications.

Polyester and epoxy resins are liquid in form and require relatively low temperatures and pressures to cure; phenolic resins are usually preimpregnated into fiber glass cloth, and require moderate oven temperatures and pressures to cure. Being compatible with fiber glass reinforcements, these resins are ideally suited for economical production of complex components. Their curing is accomplished by the chemical reaction of a catalyst or curing agent mixed with the resin. The rate and degree of curing is controlled by the catalyst, with times ranging from a few seconds to 30 days, and with temperatures varying

from 70° F (room temperature cure) to 350° F (oven cure). Usually, the greater the temperature, the quicker the cure.

Additional chemicals, mixed with thermosetting resins, render them heat-resistant, and afford other desirable properties. Pigments can be blended into the resins, particularly in the polyesters and epoxies, to produce a variety of colors. Phenolics are not as adaptable to coloring because of their natural brown state.

Fiber glass reinforcements for use with thermosetting resins are available in a number of different forms. One of the most common forms is the woven fabric that is used extensively in aircraft applications where maximum strength is desired. The three styles of fiber glass cloth most frequently used in the Convair 880 and 600 are 181, 128, and 120.

With resin added, each layer, or ply, of 181 is approximately 0.010 inch thick, 128 is 0.005 inch thick, and 120 is 0.003 inch thick after curing. In forming, the thinner material is usually placed next to the mold to insure a smooth finish. By controlling the number of fiber glass layers used in a part, very close tolerances can be maintained.

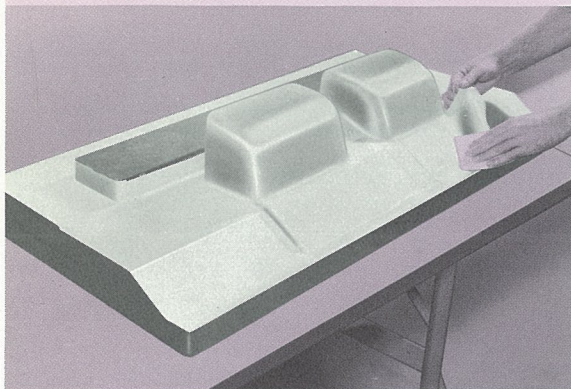
Cloth, preimpregnated with partially cured resins, is used in the molding of some parts where the resins cannot be applied in liquid form. The phenolic resins are usually preimpregnated into fiber glass cloth and are available in different stages of cure.

Several methods are used in producing fiber glass reinforced plastic aircraft parts. These include compression molding with matched metal dies, pressure bag molding, and vacuum bag molding. The vacuum bag system is used in the majority of cases where good strength-weight ratio is of importance, and where the cost of matched dies would be prohibitive. This system is ideally suited for the complex shapes of many applicable components (particularly ducts), and there seems to be no limit to the size of parts that can be produced this way. No presses are required in the vacuum bag process and the resins can be cured at room temperature or at moderate oven heat.

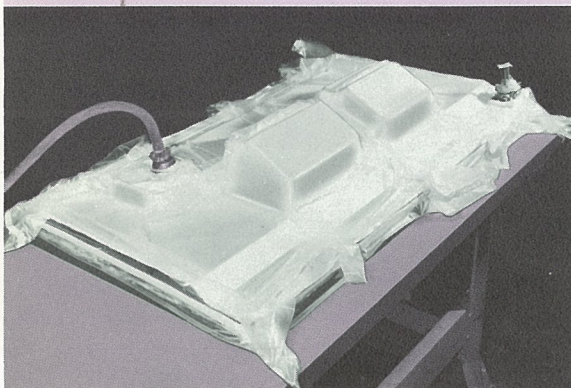
In the vacuum bag method of forming, a "lay-up" of fiber glass cloth and resin is made over a mold that has been coated with a parting agent. When preimpregnated cloth is not required, liquid resin mixed with a catalyst is applied to the dry fiber glass cloth. Layers of cloth are built up to the required part thickness and, where additional laminations or a bead are needed, glass tape or rope is applied. A channel of jute, or comparable breathing material, is positioned around the edge of the mold to enable the air to withdraw when vacuum is applied, and to allow any moisture or fumes to escape during curing.

When the "lay-up" is complete and the "breathing material" is in place, a bag or envelope of vinyl (usually polyvinyl alcohol) is placed over the "lay-up" and the edge is sealed with a bead of zinc chromate putty. The bag is fitted with an airtight vacuum outlet that is sealed against the breather channel. Vacuum is applied, and air is worked out around the part

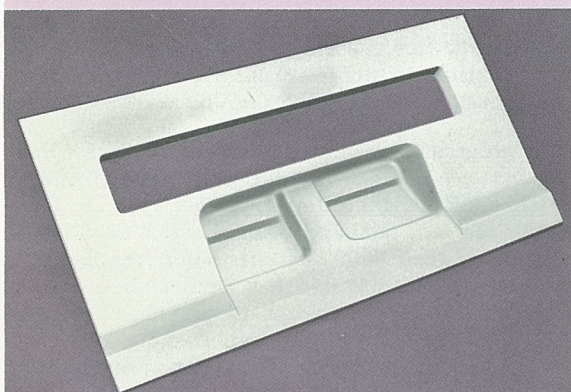
Pre-impregnated fiber glass "lay-up" over mold. Glass cloth is fitted to thickness required.



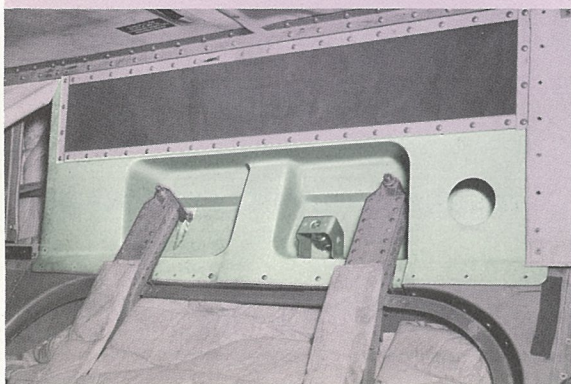
Sealed vinyl vacuum bag draws fiber glass cloth tightly against mold when suction is applied.



Formed, cured part after removal from mold. Part is trimmed and drilled before installation.



Finished fiber glass part installed in Convair 880 just above forward cargo compartment door.



(particularly at inside corners and around complex contours) until the part is held firmly against the mold.

The laminated part is cured either at room temperature or in an oven, depending on the resin, its mixture, and the production speed required. Often, the part is cured at room temperature and then placed in an oven for final curing.

After removal from the mold, the laminated fiber glass part is trimmed, machined, or drilled, if required, and hand-finished by filing and sanding.

Molds for complex parts, such as ducting, are usually cast of plaster and are removed by breaking out the plaster after the part has been cured by the vacuum bag process.

Polyester resins are among the easiest to handle. Curing takes place with no release of liquids or gas. They can be cured rapidly because of the evolved heat during the curing cycle. Since polyesters are normally light colored, they can be easily colored by the addition of pigments in the resin mix.

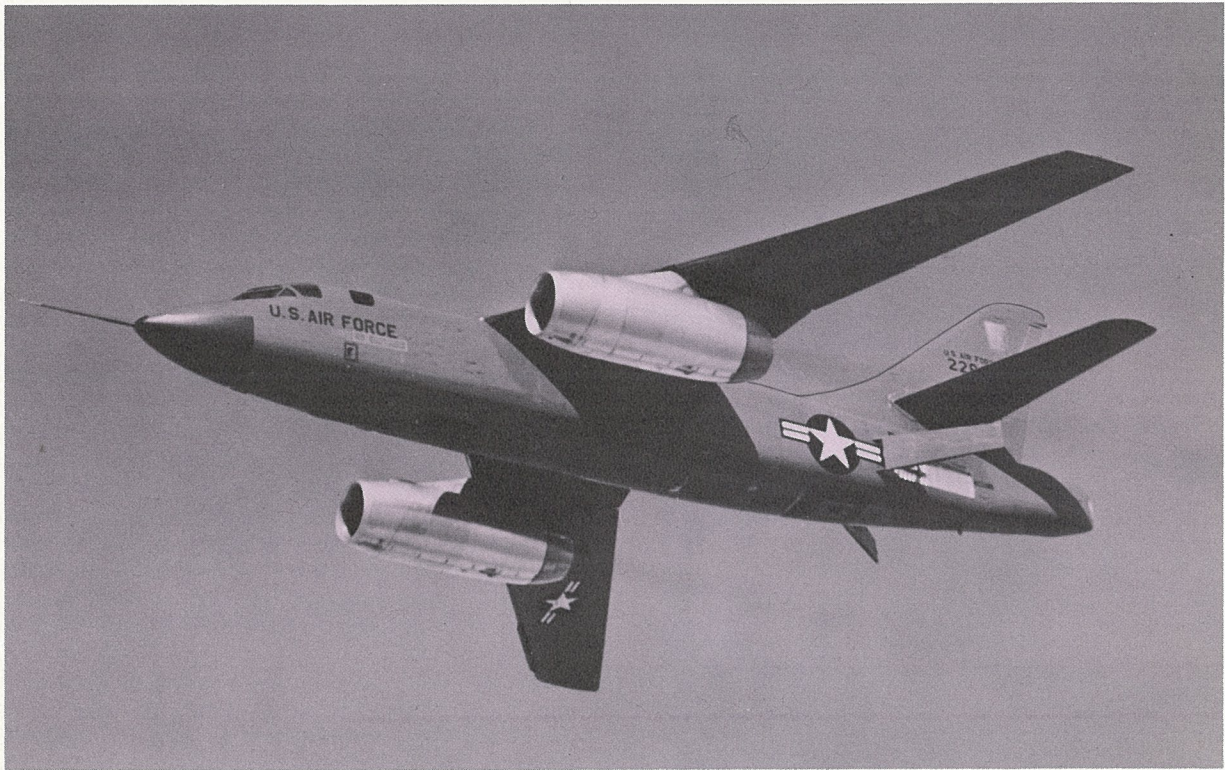
The desirable qualities of polyester, reinforced with fiber glass, are many. These include good electrical and physical properties, good weathering resistance and light stability, and good corrosion resistance. Some polyester-fiber glass laminates can withstand temperatures up to 500° F, and flame resistance is good.

Epoxy resins adhere extremely well to glass fibers and there is little shrinkage during its cure. Laminates made with epoxy and fiber glass are especially high in mechanical strength. Epoxy laminates are also outstanding in electrical resistance, and are almost entirely insensitive to humidity, oil, solvents, alkalis, and weak acids. They are unaffected within a temperature range of -76° F to + 230° F. If certain heat-resistant resins are used, the temperature range for epoxy laminates can be extended to 500° F.

Epoxy resins have exceptionally good adhesion properties. They are finding wide-spread use in the fields of glues, adhesives, and coatings. One recent development of an epoxy-based adhesive, bonds aluminum to steel with a bond strength of more than 5,000 psi. Because of their dimensional stability, epoxies are used in close tolerance parts and in tooling jigs and fixtures.

Phenolics are probably the most widely used of the thermosetting resins. They have very good mechanical strength, fair electrical properties, good resistance to chemicals and acids, and superior heat-resistant qualities.

Phenolic resins are usually cured in three separate stages, designated A, B, and C. The resin is fusible and soluble in the A stage. Applying heat advances it to the B stage where it changes to a fusible solid of limited solubility. The phenolic used in post-formable preimpregnated fiber glass fabric is usually in this B stage. Further heating of the resin advances it to the final C stage where it is fully cured—hard, insoluble, and infusible.



24 10

During the latter part of February, an RB-66, with shiny new nacelles enclosing General Electric aft-fan engines, took off on its first test flight. The engines and pods were the same type as those that will be used to power the Convair 600 jet airliner.

The noteworthy flight came off without a hitch and lasted one hour and forty minutes. This marked the first time an aft-fan engine was used as the primary power plant for powering an aircraft. Other fan engines have been used but, in each case, they were hung from the fuselage of a flying test bed and were started up after the mother ship was airborne. The 16,100-pound thrust GE aft-fan engines pushed the leased Air Force RB-66 bomber to 35,000 feet, and at speeds up to Mach .85 — exceptional performance for the first test flight of an engine.

Each of the two basic engine units installed on the RB-66 had already accumulated more than 1000

actual flight hours in the General Electric CJ805-3 (Convair 880) test program, "Operation Hightime." The simple incorporation of the aft-fan unit increases takeoff thrust by 44 percent, reduces normal cruise SFC (specific fuel consumption) by 13 per cent, and offers a higher power-to-weight ratio (4.2:1) than does any other commercial jet engine available today.

The program exemplifies the cooperative spirit that exists between Convair and the engine manufacturer for, while GE is flight testing their new aft-fan engine, Convair can get a final check on the actual flight characteristics of their "600" nacelles before the first engine is off the assembly line. It is also advantageous to be able to "marry" the engine and pod ahead of time to iron out any minor installation difficulties that might cause delays later on. The two companies beat their schedule of getting this first test flight into the air by ten days.

CONVAIR SAN DIEGO

CONVAIR DIVISION

GENERAL DYNAMICS CORPORATION

VOLUME XI NUMBER 7 NOVEMBER 1959

Convair Traveler



In this Issue: Emergency Equipment and Procedures



OUR COVER

The safety and emergency equipment that surrounds this Convair 880 jet airliner actually is to be found in the airplane, standing by to ensure the comfort and safety of crew and passengers.

The artist — Willis Goldsmith

Convair Traveler

VOLUME XI NUMBER 7 NOVEMBER 1959

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IN THIS ISSUE

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EMERGENCY EQUIPMENT AND PROCEDURES

Hugh R. Smith

PAGE 10

CONVAIR 600 AERODYNAMIC "SPEED CAPSULES"

Sam Urshan

A digest of operation and service published monthly by the Service Publications Sections of Convair Customer Service Department in the interest of Convair operators. Communications should be addressed to the Manager of Customer Service Department, Convair, San Diego 12, California. Information is to be considered accurate and authoritative as far as Convair approval is concerned. FAA approval is not to be implied unless specifically noted. Recipients of this information are cautioned not to use it for incorporation on aircraft without specific approval of their cognizant organization.

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Emergency Equipment and Procedures

Convair 880 medium-range aircraft

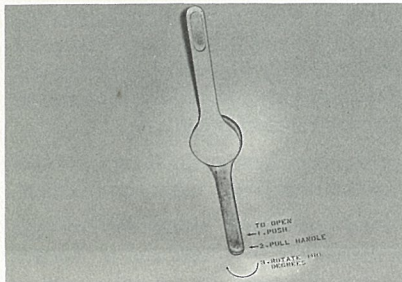
Efficient handling of an airplane in an emergency situation requires some acquaintance with its special equipment, escape provisions, and its danger areas when fire threatens.

Herein is presented a summary of some Convair 880 design features and equipment installations that will be of interest to those concerned with possible airport emergencies when the "880" begins to fly in regular airline service.

It is not the intent here to go into specific flight or ground crew operational procedures. These will be worked out in accordance with governmental regulations, operating line procedures, and airport firefighting and rescue facilities.

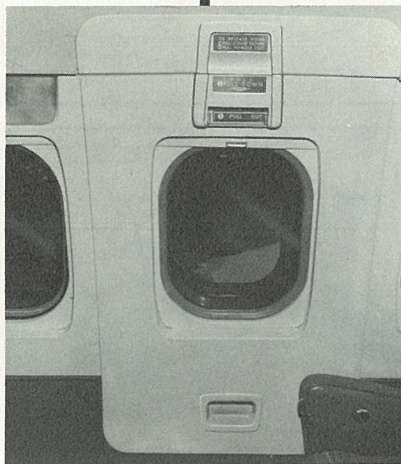
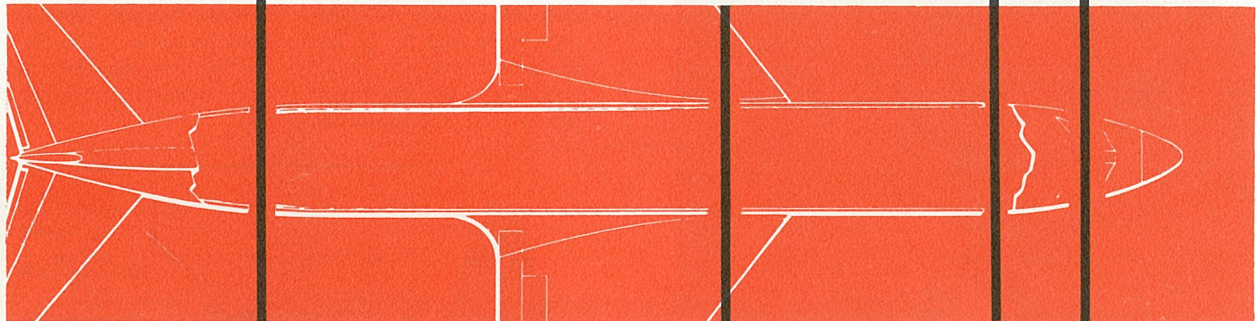
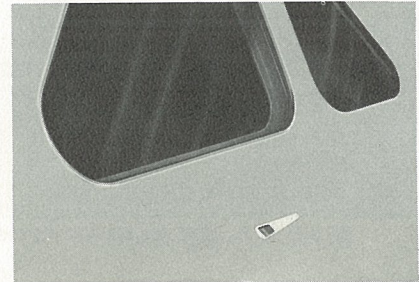
Much of the cabin and flight deck equipment is specified by the individual operator. The installations pictured herein must therefore be accepted only as typical of the medium-range "880," particularly Models 22-1 and 22-2, that will be going into service in the near future.

TO OPEN CABIN DOORS, PUSH RELEASE CATCH, PULL HANDLE, ROTATE IT 180°.

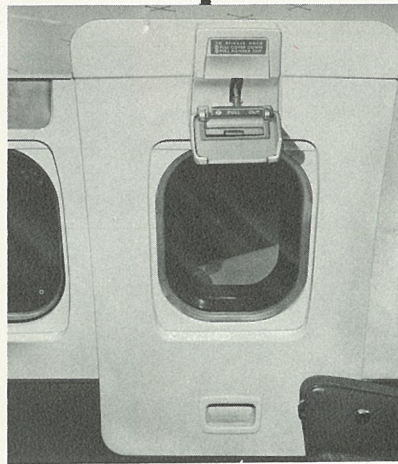


EMERGENCY EXITS

TO OPEN COCKPIT WINDOW, PUSH CATCH AND TURN HANDLE TO ROLL WINDOW AFT.



EMERGENCY HATCH INTERIOR RELEASE IS AT TOP, WITH HANDHOLD AT BOTTOM.



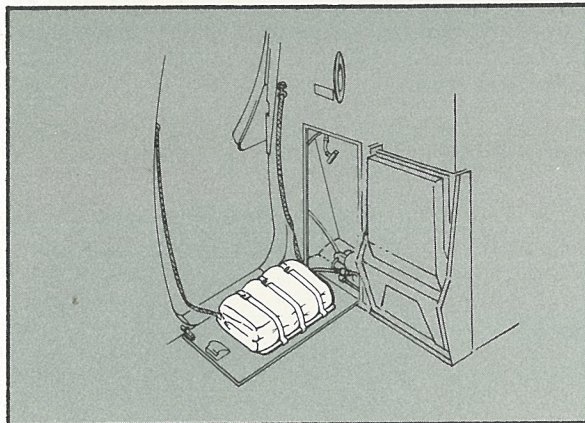
PULL COVER DOWN, PULL T-HANDLE, AND LIFT OUT THE HATCH AND LAY IT ASIDE.



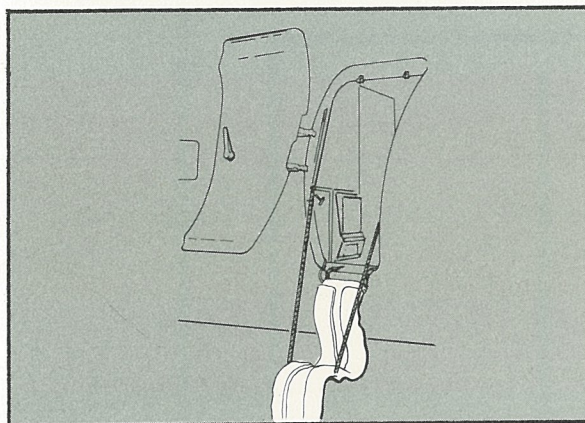
TO OPEN HATCH FROM OUTSIDE, PUSH ON PLATE TO RELEASE; PUSH HATCH IN.



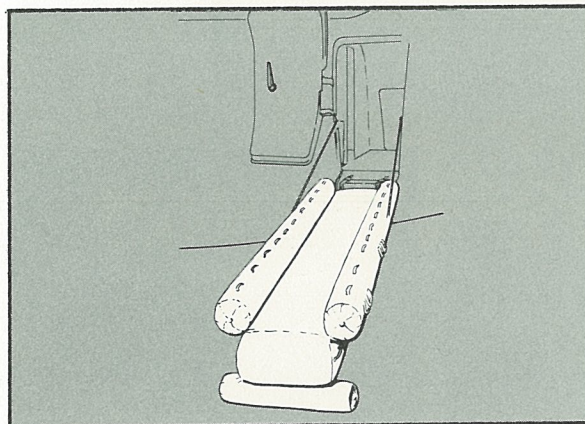
INFLATABLE SLIDE STOWAGE



STEP 1: SLIDE IN READY POSITION



STEP 2: IN POSITION FOR INFLATION



STEP 3: SLIDE FULLY INFLATED

EMERGENCY DEPLANING

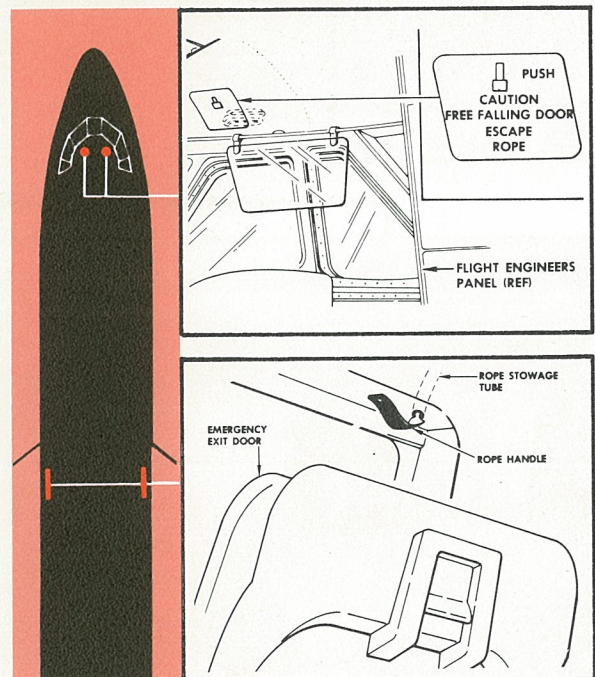
For rapid evacuation of passengers in an emergency, inflatable escape chutes are provided at forward and rear main entrance doors. Chutes at the service doors are inflatable in some versions and non-inflatable in others.

Inflatable chutes can be readied in a few seconds. The chute compartment door is dropped across the entrance, automatically releasing the packaging straps. Two support lines are hooked to each side of the door frame, the chute rolled out, and a handle pulled to release compressed air from a supply cylinder into the chute. Inflation takes only five to eight seconds.

In normal airplane attitudes, chute angle is approximately 30° at the aft entrance and 40° at the forward entrance. Even with nose gear collapsed, chute angle aft is only 43° . Handholds on the chute allow it to be held for use as a slide in event of malfunction of the inflating mechanism. In a water landing, the chute can be quickly detached at the air line and V-blocks, and will support a number of persons by use of flotation handles on each outboard side of the chute.

Non-inflatable slides require that at least two men be available to hold the slide away from the fuselage.

When the overwing emergency escape hatches are removed, a red tape attached to a rope end is exposed in the upper frame, and the rope can be pulled out to aid in climbing down from the wings. Flight compartment escape ropes are in latched compartments over the sliding windows. In some models, another rope is carried in the coat closet forward of the forward entrance, for possible use by crew members in climbing down from the main entrance when passenger loading ramps are not at hand.



ESCAPE ROPE LOCATIONS

"CHOP-THROUGH" AREAS

Should it be necessary to force entry into the cabin, the forward section, between the major splices at the wing root (Sta 640.33) and forward of the forward window (Sta 403.5) will be easiest to chop or saw through. Gage of the aluminum alloy skin is .070 between the floor and the longitudinal splice above the windows, .067 above the splice. There are no stringers from 12 inches above the floor to approximately 42 inches circumferentially from the airplane centerline. Beltframes are 19 inches center-to-center and are of .050 aluminum alloy.

Parallel cuts from just above the window frame, down alongside the beltframes to the first stringer, will make an opening approximately 1½x3 feet, and will not cut through any airplane system lines. The transverse cut may be made above the window and/or above the stringer.

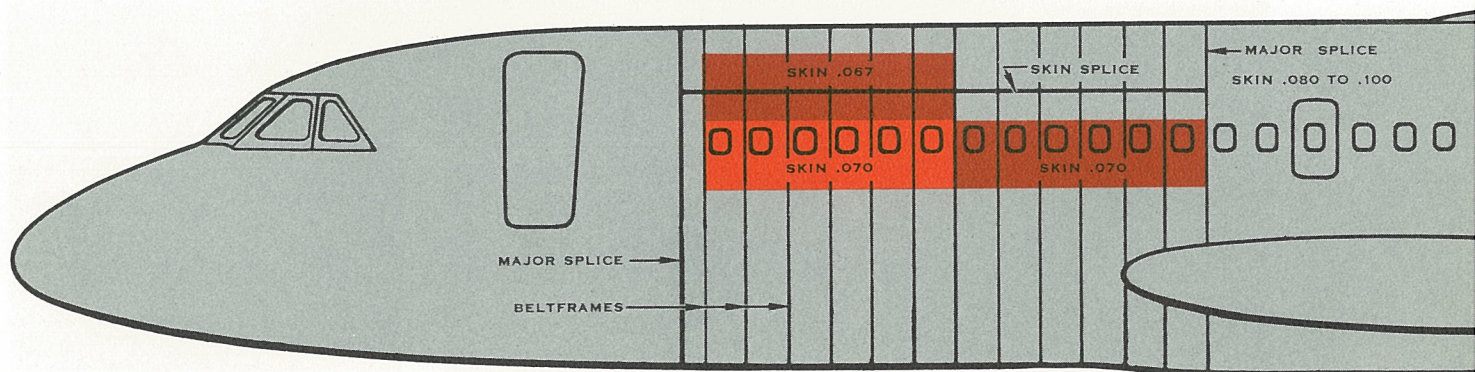
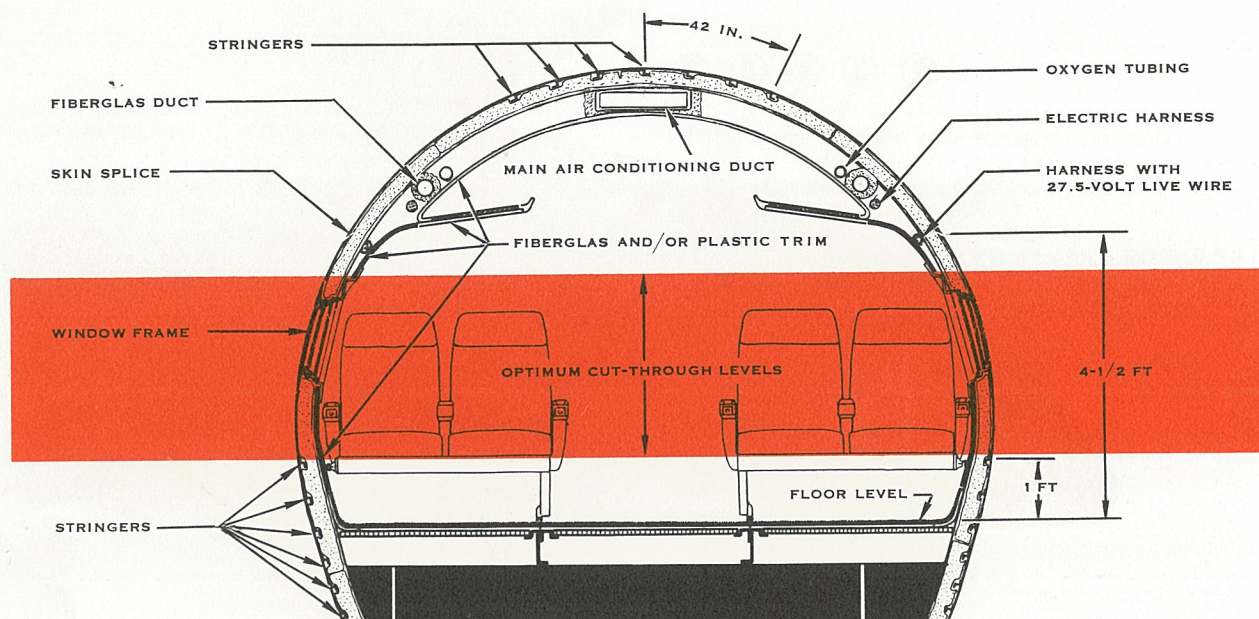
If an opening is made higher than just above the windows, the following points should be noted:

1. Approximately 8 inches above the windows is an electrical harness that will probably contain a 27.5-volt battery-energized "hot" wire. This runs to emergency exit lights and is energized by an inertia switch that trips automatically at 1½ G's, as well as by flight deck or stewardess panel switches. The inertia switch bypasses any flight deck cutoffs and hence cannot be inactivated by the crew.

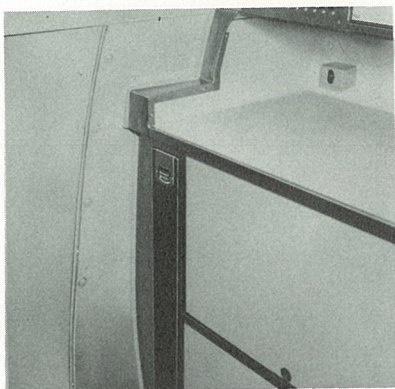
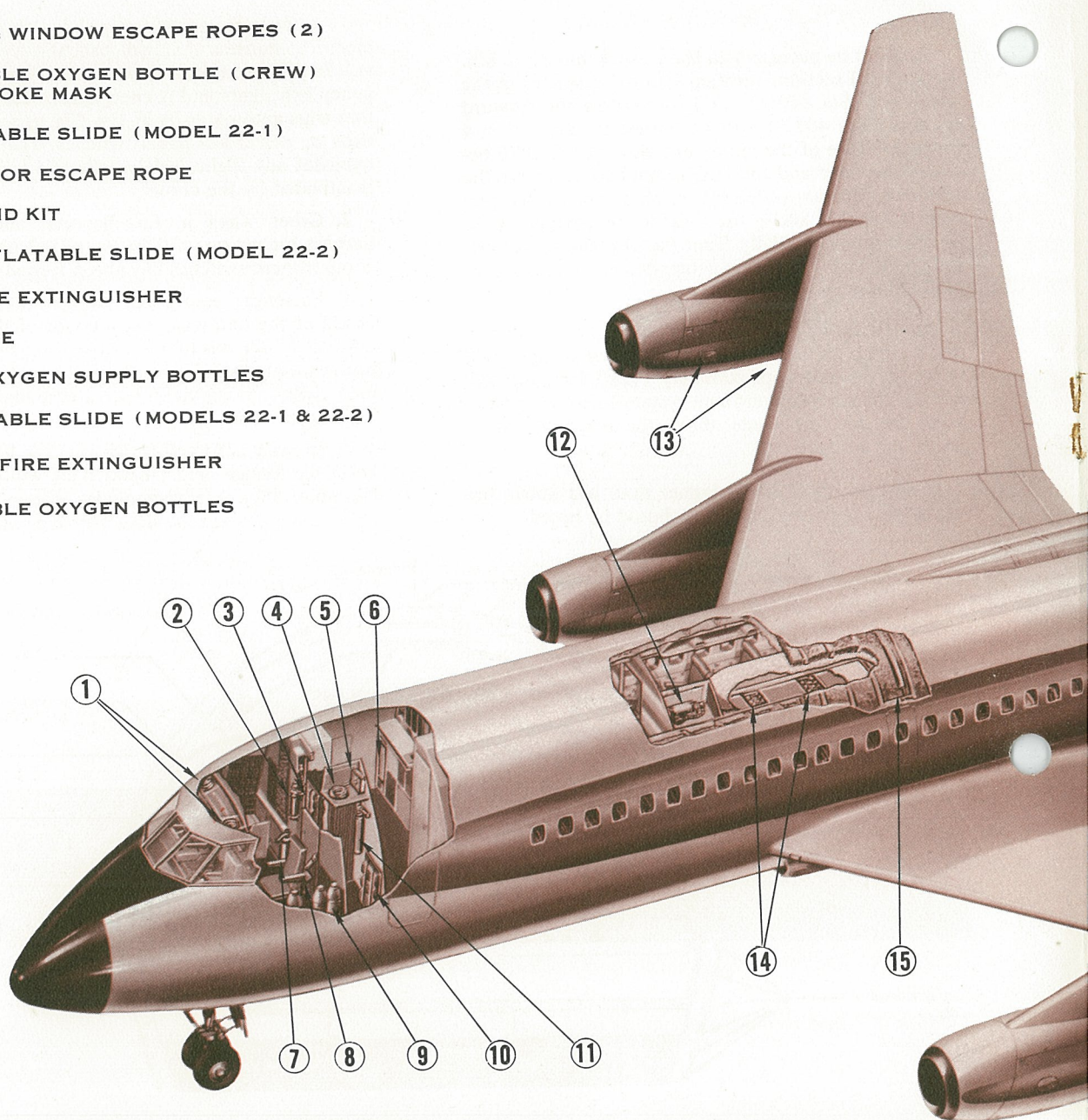
2. Other wires in this harness, and in another harness higher up, will be energized unless all flight compartment switches have been turned off.

3. Passenger emergency oxygen tubing runs outboard of the hatracks, just inboard of the ventilating air duct. While this tubing would not normally be open to the supply cylinders in the flight compartment, firemen always anticipate in such a case that oxygen may have been turned on.

4. If entry is forced above window level, it should be in the lounge area (forward six windows). Aft of this point, the center rectangular air conditioning duct "Y's" down toward the sides over the hatracks.



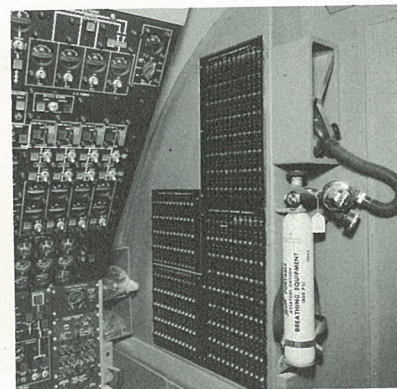
- ① SLIDING WINDOW ESCAPE ROPES (2)
- ② PORTABLE OXYGEN BOTTLE (CREW) AND SMOKE MASK
- ③ INFLATABLE SLIDE (MODEL 22-1)
- ④ FWD DOOR ESCAPE ROPE
- ⑤ FIRST-AID KIT
- ⑥ NON-INFLATABLE SLIDE (MODEL 22-2)
- ⑦ CO₂ FIRE EXTINGUISHER
- ⑧ FIRE AXE
- ⑨ MAIN OXYGEN SUPPLY BOTTLES
- ⑩ INFLATABLE SLIDE (MODELS 22-1 & 22-2)
- ⑪ WATER FIRE EXTINGUISHER
- ⑫ PORTABLE OXYGEN BOTTLES



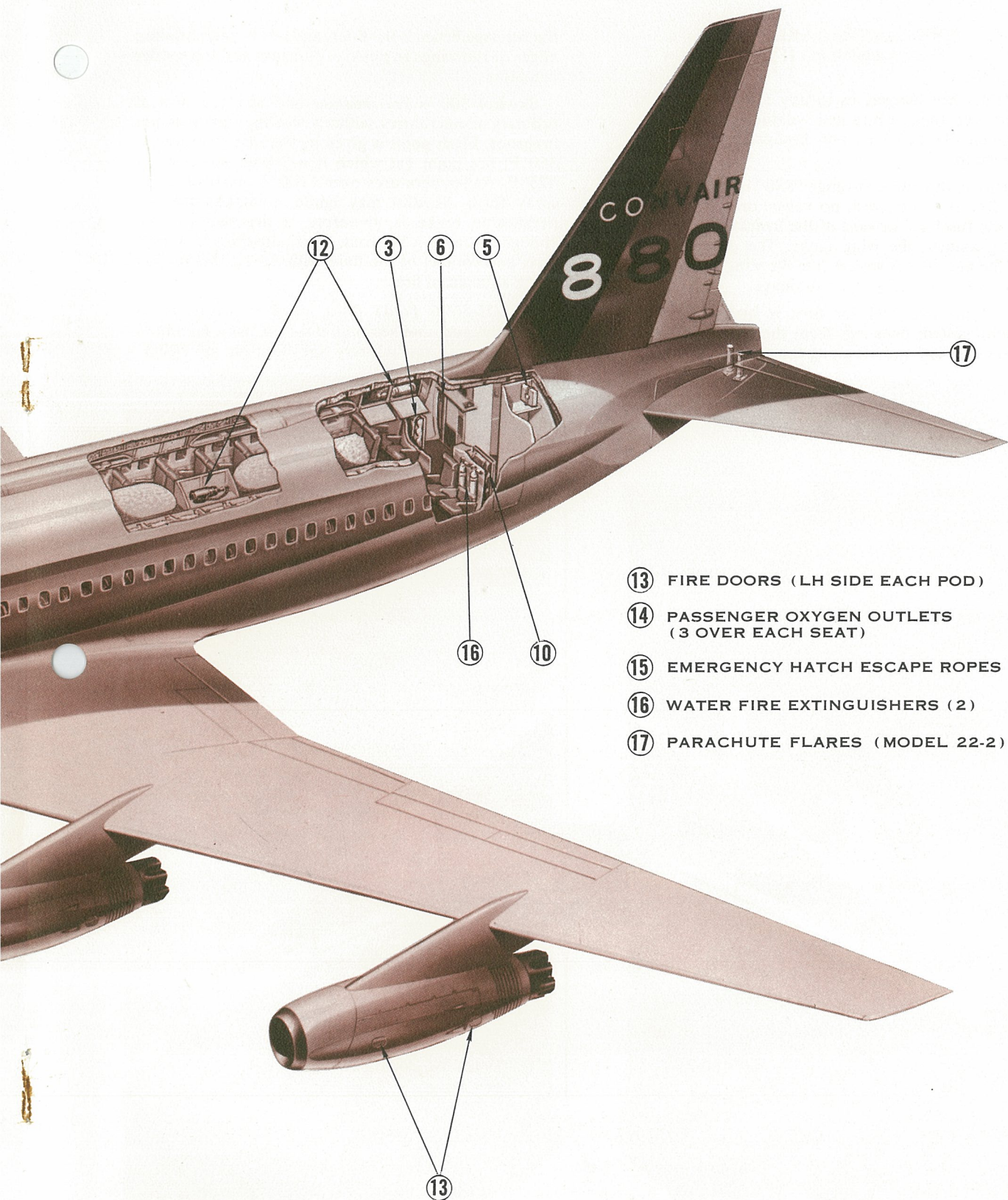
NON-INFLATABLE SLIDE STOWAGE



CO₂ FIRE EXTINGUISHER



CREW PORTABLE OXYGEN BOTTLE



- ⑬ FIRE DOORS (LH SIDE EACH POD)
- ⑭ PASSENGER OXYGEN OUTLETS
(3 OVER EACH SEAT)
- ⑮ EMERGENCY HATCH ESCAPE ROPES (2)
- ⑯ WATER FIRE EXTINGUISHERS (2)
- ⑰ PARACHUTE FLARES (MODEL 22-2)

FIRE CAUTION AREAS— Fuel and Hydraulic Fluid

Principal fire danger, as in any airplane, is from fuel. JP-type fuels, while less volatile than gasoline, burn much like gasoline, and firefighting techniques are the same.

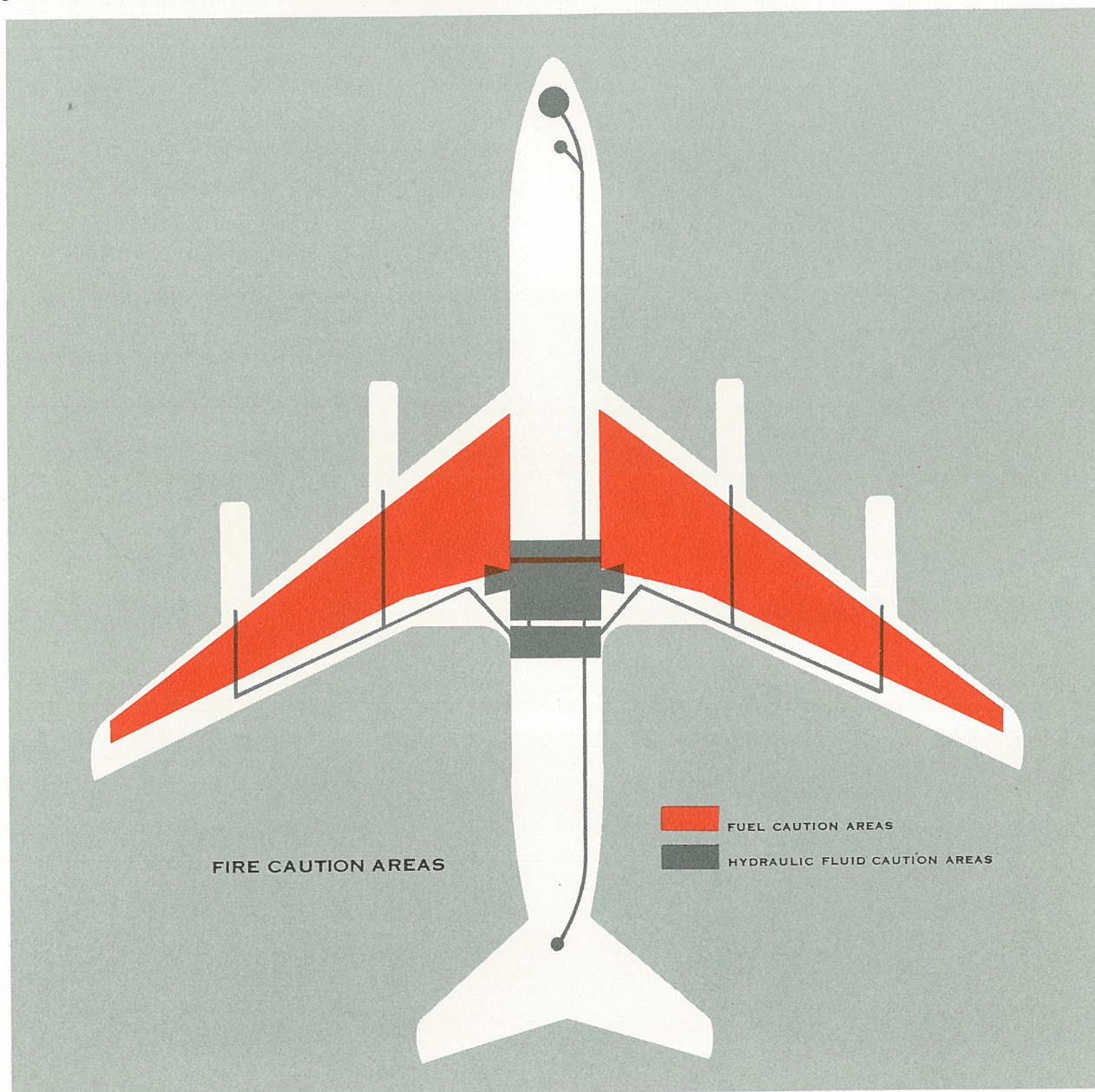
All fuel in the medium-range "880" is stored in the wings. One fuel line, with no valves or pumps, runs across the fuselage forward of the hydraulic compartment to connect the wing tanks. The area through which the line runs is sealed, like the wing tanks, with provisions for ventilation and drainage.

Second possible fuel for fires is hydraulic fluid. Hydraulic system lines run from the hydraulic compartment forward and aft along the right-hand side of

the fuselage beneath the floor, and out through trailing edges of the wings to pylon aft fairings and the spoiler actuators.

Skydrol 500 is fire resistant and will not burn at ordinary temperatures without wicking, but it is not fireproof. Flash point is given by the manufacturer as 360°F; fire point (at which it will burn steadily) as 425°F. At temperatures over 1100°F, particularly in spray form, Skydrol may ignite spontaneously. An overheated brake is, therefore, a fire peril. If hot enough to cause a blowout, hydraulic lines may rupture, and contact of the fluid with the hot brake may cause a localized fire.

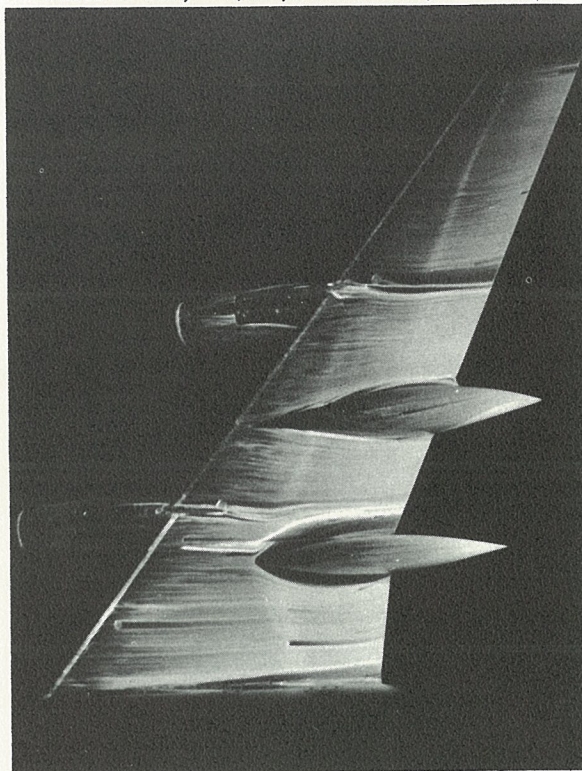
MIL-H-5606 (red) fluid, used in struts, truck positioner, and nose gear liquid spring, has a minimum flash point, by the military specification, of 200°F.



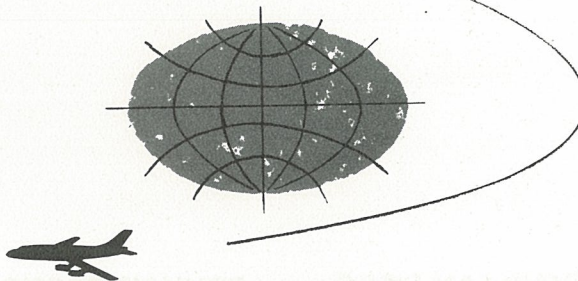
Wind tunnel photo clearly defines shock waves on a wing without aerodynamic speed capsules.



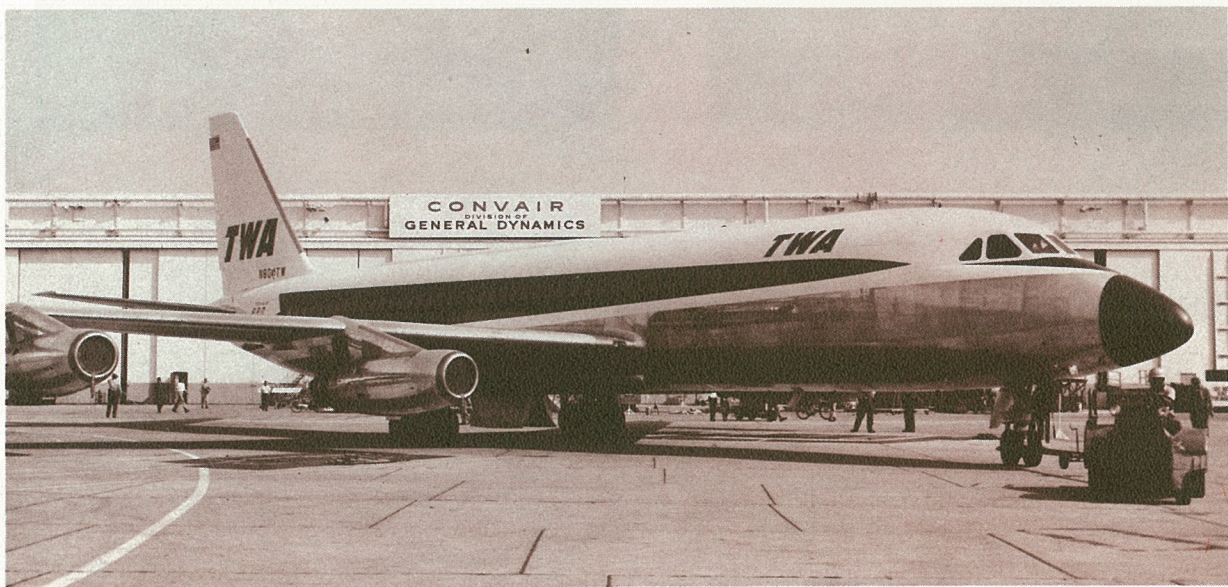
With aerodynamic speed capsules on wing, shock waves do not form, air flows smoothly over wing.



A most welcome "bonus" derived from the 600 "speed capsules" (anti-shock bodies) is the extended range made possible by utilizing the forward portion of each capsule as a fuel container. The extra 1136 gallons of fuel so carried brings the total fuel capacity to 15,108 gallons and puts the Convair 600 in the intercontinental class. The Convair 600 will be able to race the sun across the land, and win.



The first factory complete Convair 880 jet airliner, bearing the colors of Trans World Airlines, rolls away from the factory at Convair Division of General Dynamics Corporation in San Diego. This is the first of a fleet of 30 TWA Convair 880 jet airliners which will go into service next spring. The TWA Convair "880's" will have first class four-across seating, luxury interiors, and oven-equipped flight galleys for preparation of gourmet dinners. Its cabin, both forward and aft, is whisper quiet.



Aircraft industry sources have described the external noise of the four General Electric CJ805-3 jet engines as no greater than that of four-engine piston aircraft.

In more than eight months of Convair flight testing the "880" has proved itself as the world's fastest airliner with a maximum cruise true air speed of 615 miles an hour in level flight. The test program utilizing three aircraft also has proved out the "880's" ability to land and take off in distances which enable it to use airfields which accommodate present-day four-engine piston transports.

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